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ANNUAL REPORT

OF THE

BOARD OF REGENTS

OF THE

SMITHSONIAN INSTITUTION,

SHOWING THE

OPERATIONS, EXPENDITURES, AND CONDITION OF THE INSTITUTION FOR THE YEAR 1858.

WASHINGTON:
JAMES B. STEEDMAN, PRINTER.
1859.

LETTER

OF THE

SECRETARY OF THE SMITHSONIAN INSTITUTION,

COMMUNICATING

The Annual Report of the operations, expenditures, and condition of the Smithsonian Institution for the year 1858.

FEBRUARY 25, 1859.—Laid on the table, and ordered to be printed.

MARCH 2, 1859.—*Resolved,* That there be printed five thousand extra copies of the Report of the Operations of the Smithsonian Institution for the year 1858; three thousand for the use of the members of the House, and two thousand for the use of said Institution.

SMITHSONIAN INSTITUTION,
Washington, February 24, 1859.

SIR: In behalf of the Board of Regents, I have the honor to submit to the House of Representatives of the United States the Annual Report of the operations, expenditures, and condition of the Smithsonian Institution for the year 1858.

I have the honor to be, very respectfully, your obedient servant,

JOSEPH HENRY,
Secretary Smithsonian Institution.

Hon. JAMES L. ORR,
Speaker of the House of Representatives.

ANNUAL REPORT

OF THE

BOARD OF REGENTS

OF THE

SMITHSONIAN INSTITUTION,

SHOWING

THE OPERATIONS, EXPENDITURES, AND CONDITION OF THE INSTITUTION UP TO JANUARY 1, 1859, AND THE PROCEEDINGS OF THE BOARD UP TO FEBRUARY 15, 1859.

To the Senate and House of Representatives:

In obedience to the act of Congress of August 10, 1846, establishing the Smithsonian Institution, the undersigned, in behalf of the Regents, submit to Congress, as a report of the operations, expenditures, and condition of the Institution, the following documents:

1. The Annual Report of the Secretary, giving an account of the operations of the Institution during the year 1858.

2. Report of the Executive Committee, giving a general statement of the proceeds and disposition of the Smithsonian fund, and also an account of the expenditures for the year 1858.

3. Proceedings of the Board of Regents up to February 15, 1859.

4. Appendix.

Respectfully submitted.

R. B. TANEY, *Chancellor.*
JOSEPH HENRY, *Secretary.*

OFFICERS OF THE SMITHSONIAN INSTITUTION.

JAMES BUCHANAN, *Ex officio* Presiding Officer of the Institution.
ROGER B. TANEY, Chancellor of the Institution.

JOSEPH HENRY, Secretary of the Institution.
SPENCER F. BAIRD, Assistant Secretary.
W. W. SEATON, Treasurer.
WILLIAM J. RHEES, Chief Clerk.

ALEXANDER D. BACHE,
JAMES A. PEARCE,
JOSEPH G. TOTTEN, } Executive Committee.

RICHARD RUSH,
WILLIAM H. ENGLISH,
JOSEPH HENRY, } Building Committee.

REGENTS OF THE INSTITUTION.

JOHN C. BRECKINRIDGE, Vice President of the United States.
ROGER B. TANEY, Chief Justice of the United States.
JAMES G. BERRET, Mayor of the City of Washington.
JAMES A. PEARCE, member of the Senate of the United States.
JAMES M. MASON, member of the Senate of the United States.
STEPHEN A. DOUGLAS, member of the Senate of the United States.
WILLIAM H. ENGLISH, member of the House of Representatives.
L. J. GARTRELL, member of the House of Representatives.
BENJAMIN STANTON, member of the House of Representatives.
GIDEON HAWLEY, citizen of New York.
RICHARD RUSH, citizen of Pennsylvania.
GEORGE E. BADGER, citizen of North Carolina.
CORNELIUS C. FELTON, citizen of Massachusetts.
ALEXANDER D. BACHE, citizen of Washington.
JOSEPH G. TOTTEN, citizen of Washington.

MEMBERS EX OFFICIO OF THE INSTITUTION.

JAMES BUCHANAN, President of the United States.
JOHN C. BRECKINRIDGE, Vice President of the United States.
LEWIS CASS, Secretary of State.
HOWELL COBB, Secretary of the Treasury.
JOHN B. FLOYD, Secretary of War.
ISAAC TOUCEY, Secretary of the Navy.
JOSEPH HOLT, Postmaster General.
J. S. BLACK, Attorney General.
ROGER B. TANEY, Chief Justice of the United States.
WILLIAM D. BISHOP, Commissioner of Patents.
JAMES G. BERRET, Mayor of the City of Washington.

HONORARY MEMBERS.

WASHINGTON IRVING, of New York.
BENJAMIN SILLIMAN, of Connecticut.
A. B. LONGSTREET, of Mississippi.
JACOB THOMPSON, Secretary of the Interior.

PROGRAMME OF ORGANIZATION

OF THE

SMITHSONIAN INSTITUTION.

[PRESENTED IN THE FIRST ANNUAL REPORT OF THE SECRETARY, AND ADOPTED BY THE BOARD OF REGENTS, DECEMBER 13, 1847.]

INTRODUCTION.

General considerations which should serve as a guide in adopting a Plan of Organization.

1. WILL OF SMITHSON. The property is bequeathed to the United States of America, "to found at Washington, under the name of the SMITHSONIAN INSTITUTION, an establishment for the increase and diffusion of knowledge among men."

2. The bequest is for the benefit of mankind. The government of the United States is merely a trustee to carry out the design of the testator.

3. The Institution is not a national establishment, as is frequently supposed, but the establishment of an individual, and is to bear and perpetuate his name.

4. The objects of the Institution are, 1st, to increase, and 2d, to diffuse knowledge among men.

5. These two objects should not be confounded with one another. The first is to enlarge the existing stock of knowledge by the addition of new truths; and the second, to disseminate knowledge, thus increased, among men.

6. The will makes no restriction in favor of any particular kind of knowledge; hence all branches are entitled to a share of attention.

7. Knowledge can be increased by different methods of facilitating and promoting the discovery of new truths; and can be most extensively diffused among men by means of the press.

8. To effect the greatest amount of good, the organization should be such as to enable the Institution to produce results, in the way of increasing and diffusing knowledge, which cannot be produced either at all or so efficiently by the existing institutions in our country.

9. The organization should also be such as can be adopted provisionally, can be easily reduced to practice, receive modifications, or be abandoned, in whole or in part, without a sacrifice of the funds.

10. In order to compensate, in some measure, for the loss of time occasioned by the delay of eight years in establishing the Institution,

a considerable portion of the interest which has accrued should be added to the principal.

11. In proportion to the wide field of knowledge to be cultivated, the funds are small. Economy should therefore be consulted in the construction of the building; and not only the first cost of the edifice should be considered, but also the continual expense of keeping it in repair, and of the support of the establishment necessarily connected with it. There should also be but few individuals permanently supported by the Institution.

12. The plan and dimensions of the building should be determined by the plan of organization, and not the converse.

13. It should be recollected that mankind in general are to be benefitted by the bequest, and that, therefore, all unnecessary expenditure on local objects would be a perversion of the trust.

14. Besides the foregoing considerations deduced immediately from the will of Smithson, regard must be had to certain requirements of the act of Congress establishing the Institution These are, a library, a museum, and a gallery of art, with a building on a liberal scale to contain them.

SECTION I.

Plan of Organization of the Institution in accordance with the foregoing deductions from the will of Smithson.

To Increase Knowledge. It is proposed—

1. To stimulate men of talent to make original researches, by offering suitable rewards for memoirs containing new truths; and

2. To appropriate annually a portion of the income for particular researches, under the direction of suitable persons.

To Diffuse Knowledge. It is proposed—

1. To publish a series of periodical reports on the progress of the different branches of knowledge; and

2. To publish occasionally separate treatises on subjects of general interest.

DETAILS OF THE PLAN TO INCREASE KNOWLEDGE.

I.—*By stimulating researches.*

1. Facilities afforded for the production of original memoirs on all branches of knowledge.

2. The memoirs thus obtained to be published in a series of volumes, in a quarto form, and entitled Smithsonian Contributions to Knowledge.

3. No memoir on subjects of physical science to be accepted for publication which does not furnish a positive addition to human knowledge, resting on original research; and all unverified speculations to be rejected.

4. Each memoir presented to the Institution to be submitted for examination to a commission of persons of reputation for learning in

the branch to which the memoir pertains; and to be accepted for publication only in case the report of this commission is favorable.

5. The commission to be chosen by the officers of the Institution, and the name of the author, as far as practicable, concealed, unless a favorable decision be made.

6. The volumes of the memoirs to be exchanged for the transactions of literary and scientific societies, and copies to be given to all the colleges and principal libraries in this country. One part of the remaining copies may be offered for sale; and the other carefully preserved, to form complete sets of the work, to supply the demand from new institutions.

7. An abstract, or popular account, of the contents of these memoirs to be given to the public through the annual report of the Regents to Congress.

II.—*By appropriating a part of the income, annually, to special objects of research, under the direction of suitable persons.*

1. The objects, and the amount appropriated, to be recommended by counsellors of the Institution.

2. Appropriations in different years to different objects, so that, in course of time, each branch of knowledge may receive a share.

3. The results obtained from these appropriations to be published, with the memoirs before mentioned, in the volumes of the Smithsonian Contributions to Knowledge.

4. Examples of objects for which appropriations may be made.

(1.) System of extended meteorological observations for solving the problem of American storms.

(2.) Explorations in descriptive natural history, and geological, magnetical, and topographical surveys, to collect materials for the formation of a Physical Atlas of the United States.

(3.) Solution of experimental problems, such as a new determination of the weight of the earth, of the velocity of electricity, and of light; chemical analyses of soils and plants; collection and publication of scientific facts, accumulated in the offices of government.

(4.) Institution of statistical inquiries with reference to physical, moral, and political subjects.

(5.) Historical researches and accurate surveys of places celebrated in American history.

(6.) Ethnological researches, particularly with reference to the different races of men in North America; also, explorations and accurate surveys of the mounds and other remains of the ancient people of our country.

DETAILS OF THE PLAN FOR DIFFUSING KNOWLEDGE.

I.—*By the publication of a series of reports, giving an account of the new discoveries in science, and of the changes made from year to year in all branches of knowledge not strictly professional.*

1. These reports will diffuse a kind of knowledge generally interesting, but which, at present, is inaccessible to the public. Some of the

reports may be published annually, others at longer intervals, as the income of the Institution or the changes in the branches of knowledge may indicate.

2. The reports are to be prepared by collaborators eminent in the different branches of knowledge.

3. Each collaborator to be furnished with the journals and publications, domestic and foreign, necessary to the compilation of his report; to be paid a certain sum for his labors, and to be named on the title-page of the report.

4. The reports to be published in separate parts, so that persons interested in a particular branch can procure the parts relating to it without purchasing the whole.

5. These reports may be presented to Congress for partial distribution, the remaining copies to be given to literary and scientific institutions, and sold to individuals for a moderate price.

The following are some of the subjects which may be embraced in the reports:

I. PHYSICAL CLASS.

1. Physics, including astronomy, natural philosophy, chemistry, and meteorology.
2. Natural history, including botany, zoology, geology, &c.
3. Agriculture.
4. Application of science to arts.

II. MORAL AND POLITICAL CLASS.

5. Ethnology, including particular history, comparative philology, antiquities, &c.
6. Statistics and political economy.
7. Mental and moral philosophy.
8. A survey of the political events of the world, penal reform, &c.

III. LITERATURE AND THE FINE ARTS.

9. Modern literature.
10. The fine arts, and their application to the useful arts.
11. Bibliography.
12. Obituary notices of distinguished individuals.

II. *By the publication of separate treatises on subjects of general interest.*

1. These treatises may occasionally consist of valuable memoirs translated from foreign languages, or of articles prepared under the direction of the Institution, or procured by offering premiums for the best exposition of a given subject.

2. The treatises should, in all cases, be submitted to a commission of competent judges previous to their publication.

3. As examples of these treatises, expositions may be obtained of the present state of the several branches of knowledge mentioned in the table of reports.

SECTION II.

Plan of organization, in accordance with the terms of the resolutions of the Board of Regents providing for the two modes of increasing and diffusing knowledge.

1. The act of Congress establishing the Institution contemplated the formation of a library and a museum; and the Board of Regents, including these objects in the plan of organization, resolved to divide the income* into two equal parts.

2. One part to be appropriated to increase and diffuse knowledge by means of publications and researches, agreeably to the scheme before given. The other part to be appropriated to the formation of a library and a collection of objects of nature and of art.

3. These two plans are not incompatible one with another.

4. To carry out the plan before described, a library will be required, consisting, 1st, of a complete collection of the transactions and proceedings of all the learned societies in the world; 2d, of the more important current periodical publications, and other works necessary in preparing the periodical reports.

5. The Institution should make special collections, particularly of objects to illustrate and verify its own publications.

6. Also, a collection of instruments of research in all branches of experimental science.

7. With reference to the collection of books, other than those mentioned above, catalogues of all the different libraries in the United States should be procured, in order that the valuable books first purchased may be such as are not to be found in the United States.

8. Also, catalogues of memoirs, and of books and other materials, should be collected for rendering the Institution a centre of bibliographical knowledge, whence the student may be directed to any work which he may require.

9. It is believed that the collections in natural history will increase by donation as rapidly as the income of the Institution can make provision for their reception, and, therefore, it will seldom be necessary to purchase articles of this kind.

10. Attempts should be made to procure for the gallery of art casts of the most celebrated articles of ancient and modern sculpture.

11. The arts may be encouraged by providing a room, free of expense, for the exhibition of the objects of the Art-Union and other similar societies.

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*The amount of the Smithsonian bequest received into the Treasury of the United States is	$515,169 00
Interest on the same to July 1, 1846, (devoted to the erection of the building)	242,129 00
Annual income from the bequest	30,910 14

12. A small appropriation should annually be made for models of antiquities, such as those of the remains of ancient temples, &c.

13. For the present, or until the building is fully completed, besides the Secretary, no permanent assistant will be required, except one, to act as librarian.

14. The Secretary, by the law of Congress, is alone responsible to the Regents. He shall take charge of the building and property, keep a record of proceedings, discharge the duties of librarian and keeper of the museum, and may, with the consent of the Regents, employ assistants.

15. The Secretary and his assistants, during the session of Congress, will be required to illustrate new discoveries in science, and to exhibit new objects of art; distinguished individuals should also be invited to give lectures on subjects of general interest.

This programme, which was at first adopted provisionally, has become the settled policy of the Institution. The only material change is that expressed by the following resolutions adopted January 15, 1855, viz:

Resolved, That the 7th resolution, passed by the Board of Regents on the 26th of January, 1847, requiring an equal division of the income between the active operations and the museum and library, when the buildings are completed, be and it is hereby repealed.

Resolved, That hereafter the annual appropriations shall be apportioned specifically among the different objects and operations of the Institution in such manner as may, in the judgment of the Regents, be necessary and proper for each, according to its intrinsic importance, and a compliance in good faith with the law.

REPORT OF THE SECRETARY FOR 1858.

To the Board of Regents of the Smithsonian Institution:

GENTLEMEN: The principal event of importance in the history of the Institution during the past year is the transfer of the government collections from the Patent Office to the large room of the Smithsonian building.

It will be recollected that by the law of Congress incorporating this Institution "all objects of art and of foreign and curious research, and all objects of natural history, plants, and geological and mineralogical specimens belonging to or hereafter to belong to the United States which may be in the city of Washington, in whosesoever custody the same may be, shall be delivered to such persons as may be authorized by the Board of Regents to receive them."

The law thus giving to the Smithsonian Institution all specimens illustrative of nature and art to be found in the several offices and departments of government was not construed as rendering it obligatory on the Regents to accept these objects if they considered it inexpedient to do so. Inasmuch, then, as this collection was neither essential to the plan of organization nor directly subservient to the comprehensive purpose of the donor in regard to a world-wide benefit, it was the ultimate decision of a majority of the Board that it ought not to be accepted and that no part of the donation ought to be expended in the care of property belonging to the government of the United States.

Previous to the discussion of this question it had been assumed that the Regents were under an obligation to take charge of the museum, and, on this account principally, a large and expensive building had been thought necessary. After it was settled, however, that the Regents were not bound to accept this trust, the work of construction was carried on more slowly, with a view at once to secure certain advantages to the building itself, and to increase the principal by funding the interest of the money which would be absorbed by its completion.

In the meantime a very large amount of specimens of natural his-

tory had accumulated at the Institution from numerous exploring parties sent out by the general government; and as these collections had been made under the direction of the Institution, and their preservation was of the highest importance to the natural history of the country, it was finally concluded that if Congress would make an appropriation for the transfer and new arrangement of the articles then in the Patent Office, and continue the annual appropriation previously made for their care and exhibition while in charge of the Commissioner of Patents, the Institution would, under these conditions, become the curator of the national collections. This proposition was agreed to by the government, and the contemplated transfer has accordingly been made.

It is believed that this arrangement will be mutually beneficial to the Patent Office and the Institution, since the former will be relieved from a duty scarcely compatible with the design of its establishment, and will gain possession of one of the largest rooms in the city for the exhibition of a class of models to which the public have not previously had ready access; while the Smithsonian Institution will be able to present to the strangers who visit Washington a greater number of objects of interest, and appropriate that portion of the large building not required for its own most important operations to a useful purpose.

The cost of keeping the collections at the Patent Office, including fuel, was about $4,000 annually, but the Regents might with justice have asked for an additional amount sufficient to pay the interest on the cost of that portion of the edifice occupied by the museum. It was, however, thought more prudent to restrict the application to the sum above mentioned, and to request that the appropriation might be continued under the charge of the Secretary of the Interior, thus obviating the necessity of an annual application to Congress by the Institution itself.

The cases at present required for the accommodation of the collections have been constructed at a cost within the appropriation made for that purpose; and the Institution is indebted to Hon. J. Thompson, Secretary of the Interior, and Hon. J. Holt, Commissioner of Patents, for the use of glass sash and shelving no longer needed in the room which formerly contained the museum in the Patent Office, but which have been applied to good purpose in supplying deficiencies in the Smithsonian building. The Regents are also indebted to Thos.

U. Walter, esq., architect of the United States Capitol extension, for the beautiful design of the cases, and to Edw. Clark, esq., architect of the Interior Department, for the inspection of the work during its progress and the examination of the accounts presented by the contractor.

In order to increase the capacity of the large room appropriated to the collection, the cases have been arranged in two stories, forming a series of alcoves and a gallery on each side. By the adoption of this plan space can be provided for double the number of specimens which were exhibited at the Patent Office.

A considerable portion of the collections has been arranged, and a taxidermist employed to repair the specimens of zoology which have been damaged, and to prepare for exhibition others which had not previously been mounted. The museum will soon be an object of continued and increasing interest to the inhabitants of the city and to strangers who visit the capital of the United States.

Among the specimens many duplicates occur which might be advantageously distributed perhaps to the principal societies of natural history in this and other countries; and I respectfully ask the Board of Regents to determine, regarding this point, whether, in their judgment, the Institution can venture to make such distribution without further instruction from Congress. If within its power, this measure would seem evidently calculated to further one of the legitimate ends of the Institution in diffusing more widely the materials of science and the means of education.

An assent to the arrangement above stated for taking charge of the government collections is by no means inconsistent with the regret expressed in previous reports that the law of Congress directed provision to be made from the Smithsonian fund for a public museum and library. It must be evident to any one who attentively studies the past history of the operations of the Institution that the interest of the money expended on the building intended for this purpose would have been much more efficiently applied in the development and publication of new truths. But, in all cases where many views are to be consulted, the question is not merely what *ought* to be, but what *can* be accomplished. From the first there has existed a clear conception of the means by which the idea of the donor could be best realized, and the aim of the majority of the Regents has continually been to approximate, as nearly as the restrictions of Congress would allow, to the plan originally proposed. The policy has been invariably the

same, and the present reputation and generally acknowledged success of the Institution are the result of this undeviating course.

It is a matter of congratulation to be able to announce to the Board the continued prosperous financial condition of the Institution. The investment of the extra fund in State stocks has proved to be judicious. They now yield the Institution an annual income of upwards of seven thousand dollars. It may also be mentioned in this place, as a fact of interest to the friends of the Institution, that from the report of the governor of Arkansas it appears that the original fund received by the United States from Smithson's bequest, and lent by the government to that State, will in due time be repaid, and that the general government will in no respect be a loser by having accepted the charge and administration of this trust.

The income of the Institution being payable periodically on the 1st January and 1st July, it is obvious that the current expenses, which are continuous, cannot all be met as they accrue. An effort has therefore been made for the last two years so to curtail the expenditure as to accumulate in the treasury a half year's interest. This object will be fully accomplished during the next year. For the future, therefore, we shall be enabled to pay cash for printing, paper, &c., and thus save a considerable per centage on the cost of these articles.

Comparatively few repairs have been required during the past year on the building, though the changes which have been necessary to accommodate the increasing operations of the Institution have involved considerable expense. The corridors, which were entirely open to the northwest wind, have been enclosed with glazed sashes; a large amount of space has thus been rendered available, and a considerable portion of the interior of the building protected from the inclemency of the weather.

The heating of the building is a heavy item of expense, and must continue to be so until double windows can be furnished, particularly on the north side, and a more economical as well as efficient method of warming be adopted. The whole length of the building is four hundred and fifty feet, one-third of which, at least, is occupied by a series of windows, through which the heat of the air within so rapidly escapes by contact with the cold glass that the cost of inner windows would be saved in the course of a few years.

The smaller rooms are mostly heated by stoves, and the larger ones by furnaces. Estimates have been procured for substituting hot water

apparatus, but the expense of introducing this method is so great that we would hesitate to advise its adoption at present.

It may be proper again to mention the fact that the grounds on which the Smithsonian building stands, are under the charge of the Commissioner of Public Buildings, and that, though several thousand dollars of the income of the Smithsonian fund were originally expended for their improvement, the Institution has surrendered all control over them. It is believed, however, that Congress will in due time make a more liberal appropriation for the improvement of the public Mall, of which the Smithsonian reservation, as it is sometimes called, forms a part, and for carrying out the original design of the lamented Downing, which connects in one common plan a succession of enclosed parks, extending from the Capitol to the Potomac.

The proposition to supply the public grounds with a complete series of American trees has long been contemplated, but as no appropriation has been made by Congress for this purpose, the Patent Office, conjointly with this Institution, has taken the preliminary steps by issuing a circular asking for seeds of every species of our forest trees and shrubs that would be likely to thrive in this latitude. This circular has been widely distributed, and it is hoped will meet with a favorable response from all who are interested in making more generally known, and in introducing into more extensive cultivation, the natural ornamental products of our own soil. The seeds are to be sent by mail to the Commissioner of Patents, and placed in charge of the officers having the care of the public grounds.

It may be mentioned in this connexion that the original plan of Captain Meigs for the supply of the city with water contemplates a series of fountains to ornament the public reservations. To the same valuable improvement we shall also owe the introduction, probably during the present year, of a full supply of Potomac water into the Smithsonian building.

Publications.—The publications of the Institution may at present be divided into three classes: 1st, the "Contributions to Knowledge," in quarto form; 2d, the annual report to Congress, printed at the expense of government; 3d, irregular series, such as the meteorological and physical tables, directions for observations, special reports, &c., in octavo, to which has been given the name of "Smithsonian Miscellaneous Collections."

The tenth volume of the Contributions has been printed, and is

now ready for distribution. It contains the third and concluding part of the Nereis Boreali Americana, a Grammar and Dictionary of the Yoruba Language, and the magnetic observations made under the direction of Dr. Kane during his last Arctic expedition.

The issuing of this volume has been delayed on account of the interruption in the printing of the Yoruba Grammar, caused by the absence of the author, the Rev. Mr. Bowen. It was, however, essentially completed within the year 1858, and will bear that date.

The articles which the volume contains have been described in previous reports, with the exception of the magnetic observations made by Dr. Kane.

1. It will probably be recollected that the plan of exploration proposed by Dr. Kane for his last voyage was recommended to the favorable attention of the Secretary of the Navy by the Smithsonian and other institutions, and that the expedition was furnished with magnetic and meteorological instruments jointly by the Coast Survey and this Institution. The observations above mentioned are a part of those which were made with these instruments. They were reduced and prepared for publication at the expense of the Institution, under the direction of Professor Bache, by Charles A. Schott, esq., and form additions to our knowledge of the direction and intensity of the magnetic force in the inhospitable regions of the north, of sufficient value to fully justify the interest which was taken in promoting the organization and the fitting out of the expedition.

The following extracts from the remarks of Professor Bache to the American Association will serve to exhibit the light in which these observations were regarded by him, nor can they be otherwise than acceptable as the expression of an opinion in which all will concur who were acquainted with our lamented fellow countryman, or who are capable of appreciating his labors:

"The scientific reader of the narrative of the second Arctic expedition would be struck by the fact that while in the preface Dr. Kane disclaimed all pretensions of a scientific character for his work, it contained, nevertheless, some of the most important contributions to our knowledge of the natural history and physical phenomena of the interesting regions visited by the intrepid explorers. Dr. Kane appreciated highly all the relations, direct and indirect, which science has to an exploring expedition. He was ever careful to surround himself with those who could, in their special departments, make valuable

observations, while his own rare administrative capacity always gave them opportunity for the exercise of their abilities. Himself an admirable observer and well trained in the use of instruments, he was always at hand to direct or to assist, as the occasion might require. The labors in physical observation of Dr. Kane and his associates had few parallels when the difficulties to be surmounted and the results produced are considered.''

The magnetic observations were properly placed in the hands of Mr. Schott for discussion, as he had been selected for similar service by Dr. Kane himself, and felt a strong interest in the work. The principal magnetical results were obtained on the coast of Greenland during the years 1853-'54-'55, and in regard to the high magnetic and geographical latitudes in which the observations were made, as well as the completeness of the observations for diurnal changes of the horizontal needle at a station before unknown to geography, ''they deserve,'' says Professor Bache, ''the attention of those engaged in the study of the law of the changes of the magnetic elements in the Arctic regions.'' At a late meeting of the British Association resolutions were passed making application to the English government to send a vessel to the vicinity of Mackenzie river to institute observations with special reference to the determination of the laws now known to govern the magnetic storms. The resolutions also insist on the importance of observations in the northern regions. Captain Younghusband, of the royal navy, remarks, in his discussion of those of Sir John Richardson, that ''so few observations of the diurnal variation of the declination in high latitudes are up to this time at command, that not even an approach can be made towards indicating a general law of the phenomena in such localities.''

The Winter Quarters at Van Rensselaer Harbor, where most of the observations of Dr. Kane were made, is in latitude 78° 37′, to the northward and eastward of Cape Alexander, beyond Smith's sound.

The following is an outline of the discussion and of the results obtained by Mr. Schott from Dr. Kane's magnetic observations at Van Rensselaer Harbor. The *diurnal ranges of the declination* were deduced from observations on seventeen days in January, February, and March, 1854. The mean diurnal range or motion of the needle was found equal to 2° 29′, and the greatest range observed amounted to 4° 52′. The results were compared with similar ones at Lake Athabasca, Fort Simpson, and Port Bowen. A classification was made of the observed ranges according to their frequency and magnitude. The

values of the *diurnal inequality of the declination* were deduced for every hour (mean local time) and also compared with similar values for the same period observed at Greenwich. This inequality at these two stations presents, in general, the same characteristic features, namely: the principal deflection of the needle to the west shortly after noon, and the opposite eastern deflection about midnight. The extreme westerly position at Van Rensselaer Harbor is attained at noon; the easterly extreme is reached at 2 a. m. A small disturbance is noted at the hours of 4 and 5 p. m. While the diurnal variation agrees with that observed at Lake Athabasca, Fort Simpson, Sitka, Toronto, &c., it shows no trace of that marked deviation exhibited at Reikiavik, in Iceland, and Fort Confidence. The results were further compared with similar ones at Whalefish islands and Port Bowen. The range of the mean diurnal inequality was 1° 7′.

The mean disturbance of the declination for each hour was found greater than at Lake Athabasca and Fort Simpson. The disturbing force is least from 10 a. m. to 7 p. m., and greatest and equally regular from 8 p. m. to 8 or 9 a. m. At noon, as at Lake Athabasca, Toronto, and Sitka, an increase in the mean disturbance is noticed. The minimum disturbance takes place at 5 p. m. The mean monthly disturbance was greatest in February. The recognition and separation of the disturbed observations was effected by application of a method proposed by Professor Peirce, according to which, one in every eighteen of the whole number was found disturbed, that is, differing more than 1° 38′ from the mean, while at Toronto the disturbance was one in every seventeen. The *aurora borealis* was carefully noted, and in no case did the needle show any special deviation during its occurrence—a remarkable circumstance, in consideration of the fact of the great disturbances noted during the appearance of this phenomenon farther south.

The term-day observations, made once in each month, from January to July, 1854, were exhibited graphically, and compared with corresponding observations at Washington and Greenwich. The observations are marked by the absence of any considerable disturbance, and by the small diurnal range at the time of the equinox. The *absolute declination* was determined on three days in June, 1854, and found to be 108° 12′ west. The *magnetic inclination* was obtained at ten stations, which gave for Van Rensselaer's Harbor a dip of 84° 45′.8 from observations between January, 1854, and May, 1855.

The magnetic intensity was derived from observations of deflections and vibrations made between January, 1854, and May, 1855, the magnetic moment of the magnet having been determined at Washington. From twenty-three separate values the horizontal intensity was found equal to 1.139, corresponding to the epoch of June, 1854. The total force was 12.48. In the summer of 1855 the horizontal intensity at Hakluyt island was found to be 1.344, and at Cape York 1.573.

The remaining series of the Arctic observations under the direction of Dr. Kane are still in process of reduction; though a portion of the tabular matter has been sent to the printer to avoid delay in the publication, and will be included in the eleventh volume of Smithsonian Contributions. They relate to temperature, winds, moon culminations, twilight, halos, moisture, atmospheric pressure, and tides. The mere enumeration of the objects which engaged the active mind of the distinguished explorer, is sufficient, when we consider his feeble physical powers, to account for the untimely loss which science and humanity have been called on to deplore.

2. Another paper shortly to be put to press consists of an account of the results of a series of physical observations by Dr. Luis Berlandier, the notice of which may perhaps be best introduced by a statement of the following facts given in my Report to the Regents for 1854. Dr. Luis Berlandier, a member of the Academy of Geneva, visited Mexico in 1826 for the purpose of making a scientific examination of the country. Soon after his arrival he was appointed one of a commission, organized by the then new republic, with the object of defining the boundaries, extent, natural resources, &c., of the northern or frontier States. The position gave him unusual facilities for observation relative to the character of the country, and for making collections to illustrate its natural history. He, however, never returned to his native country, but married and settled in Mexico, and there continued his researches until the period of his death in 1851. In the year 1853 Lieutenant Couch, U. S. A., made a scientific exploration in Mexico under the auspices of the Institution, and was so fortunate as to procure the manuscripts and collections of Dr. Berlandier. He presented to this Institution all of those which related to meteorology and natural history, and offered to sell to the government at a low price the remainder, containing historical and geographical information, chiefly pertaining to the States of the old republic which lay between the Sabine and the Sierra Madre. It is to be regretted that this proposition was not accepted, since in

order to reimburse himself for the original cost of the manuscripts he was induced to dispose of them to a private individual.

The portions of the manuscripts relating to meteorology were placed in the hands of Professor Coffin for reduction. They consist, either in summary or in detail, of the results of a series of nearly three hundred and fifty thousand observations commenced at Havre, France, October 14, 1826, and continued during the voyage of Dr. Berlandier to Tampico, and afterwards at intervals in various parts of Mexico, chiefly at Matamoras, till April 26, 1851; also, of a series taken at the city of Mexico, in 1827, by General Teran, and at Goliad, Texas, in 1832 and 1833, by Dr. Raphael Chowell. The whole had been collected and arranged with care by Dr. Berlandier, preparatory to a thorough reduction, which was intended to show not only the mean results, but all the more important relations existing between different atmospheric phenomena, when death closed his labors, and put an end to his interesting and useful investigations.

3. The family of the lamented Dr. Hare has presented to the Institution a paper describing an instrument denominated by its author a cycloidegraph. It is intended to illustrate the motions of particles of air when subjected to a gyratory or whirling motion, combined with one of translation. This instrument, of which a drawing will be given, evinces the ingenuity and power of mechanical combinations, of which Dr. Hare gave so many manifestations during the long course of his industrious and successful scientific career.

The paper is accompanied by engraved illustrations of the curves produced by the machine, and contains a series of propositions intended to demonstrate the centripetal theory of storms. As the last contribution to physical science of one of the patrons of the Smithsonian Institution, and its first honorary member, it is proper that it should find a place in the Smithsonian Contributions to Knowledge.

4. The next communication to be mentioned, is an account of observations made on the great solar eclipse of September 7, 1858, in which the total shadow of the moon passed obliquely over South America, a few degrees south of the equator. Accurate observations of the phenomena presented during the total obscuration of the sun afford such important means of enlarging our knowledge of the physical character of that luminary, and the event is of such rare occurrence, that the opportunity to study the phenomena should never be neglected. The Smithsonian Institution, therefore, readily agreed to a proposition made by Lieutenant Gilliss, to undertake the observation

of the eclipse, if an appropriation could be made sufficient to pay at least a portion of his expenses and his free passage procured. In accordance with this proposition letters were addressed to the British Pacific Steam Navigation Company, to the United States Mail Steamship Company, to the Pacific Mail Steamship Company, and to the Panama Railroad Company, setting forth the objects of the expedition, and asking for free transportation for Lieutenant Gilliss and his instruments, and for such other facilities as it might be in their power to bestow. This request was generously complied with; not only were free passages granted to himself and his companion, but every other facility was proffered which it was in the power of the officers of the companies to afford.

The British Pacific Steam Navigation Company not only furnished with great cordiality free transport, but so instructed their agents on the coast, that when an accident on the Panama railroad separated Lieutenant Gilliss from his instruments, and caused a delay in their arrival, the steamer bound to Payta waited in port several hours for them. When returning home, the commander of another steamer of the same line was instructed to make all possible speed in reaching Panama, so as to save Lieutenant Gilliss the detention of two weeks which passengers coming to the United States from the South Pacific frequently experience. For the acts of enlightened liberality on the the part of the above-mentioned companies in facilitating the advance of science, special acknowledgment by resolution immediately from the Board of Regents is due.

The necessary meteorological instruments were furnished by the Institution; the astronomical by the National Observatory, the Coast Survey, and Mr. Henry Fitz, of New York.

Lieutenant Gilliss, though highly favored with the necessary means of accomplishing the desired result, encountered many difficulties in reaching the proper spot at which to make the observations. Accompanied by Mr. C. H. Raymond, of New York, he arrived at Payta, Peru, on the 21st of August, 1858. The French admiral commanding in the Pacific placed the war steamer Mégére at his disposition, should it be desirable to proceed to any other point on the coast. Information, however, obtained from residents, and his own experience during the ensuing eight days, convinced him that there was little probability of a clear sky in the morning near the sea. But, in order to obtain observations from a second party, should clear weather occur there, he arranged with the commandant of the Mégére to pro-

ceed with the vessel to a point south of Payta, where the eclipse would be total, and furnished him with a telescope and a special chronometer for the use of the officers selected to make the observations on shore. The accounts of these gentlemen are embraced in the report of Lieutenant Gilliss to the Institution.

Leaving Payta, on the morning of August 29, with such instruments as it was possible to transport on mules across the desert in the northern part of Peru, Lieutenant Gilliss proceeded to Olmos, a small town within the outer range of the Andes, and in approximate latitude 6° south, longitude 80° 10′ west. Illness prevented his reaching the summit of the Andes, as he intended, and on the 5th of September he encamped on an eminence one mile southeast from Olmos, and almost on the central line traversed by the moon's shadow. From August 21 until the day of the eclipse, there had been but two clear mornings. On all the other days the sky was obscured until after 9 a. m., before which time the eclipse terminated. It was also cloudy at sunrise of the 7th, and until after the eclipse had commenced; but as it progressed the thin masses of vapor rapidly rolled from a portion of the sky, and for some time before and after total obscuration only a delicate film of mist intervened between the observer and the moon. The observations, though unpromising at the beginning, were highly successful.

The different astronomical phases of the eclipse were determined with accuracy, and thus afford data for the improvement of the solar and lunar tables. Interesting facts were also obtained in regard to a phenomenon which has attracted much attention during later eclipses, and is known under the name of the pink-colored protuberances or flame-like appearances projecting from the sun beyond the limb of the moon. Simultaneously with the total obscuration of the sun, Lieutenant Gilliss observed four marked protuberances of this character beyond the lunar disk, one of them being more than 30° of the sun's circumference in extent. Their elevation did not exceed 1′ or 1′ 10″ of the celestial arc, the largest one being scarcely half that altitude. They resembled clouds, the thinner portions of which transmitted the sunlight, but were wholly destitute of the rose color hitherto observed in total solar eclipses, and seen on this occasion by the French officers at Sechura bay. Those to the west and north continued visible for one or two seconds after the sun's limb was uncovered. These prominences were plainly visible to the unassisted eye, and their proximate position and the absence of expected red color

were also noted by Mr. Raymond, who had been charged with the meteorological observations. The total eclipse lasted $60\frac{1}{2}$ seconds. A corona light appeared at the same time as the solar clouds, extending from the sun farthest in radial lines drawn from the centre, and passing through the clouds, but was nowhere traceable more than 15′ or 16′ from the solar disk. There was no appearance of fasces or bundles of rays, but only a uniformly diminishing and slightly orange tinted light, whose brightness and extent were apparently influenced by the film of mist. It vanished with the first appearance of the sun.

As already stated, Lieutenant Gilliss was accompanied by Mr. Carrington H. Raymond, of New York, who rendered him essential assistance during the whole expedition, as well as at the time of the eclipse.

The communication of Lieutenant Gilliss will be accompanied by a drawing of the appearance of the eclipse at the time of greatest obscuration, and will form a part of the eleventh volume of the Smithsonian Contributions.

5. The investigations of Mr. Meech relative to the heat and light of the sun have been continued during the past year and are still in progress. The memoir containing the result of these investigations obtained previous to September, 1855, was published as a part of the ninth volume of the Smithsonian Contributions, and has received the approbation of the scientific world. It is noticed with credit to the Institution in the proceedings of the Astronomical Society of London, and in a letter on the subject from Sir John Herschel.

The memoir already published contains a discussion of solar heat in all its astronomic phases at the exterior of the earth's atmosphere. The labors of Mr. Meech have since been directed to the partial absorption or extinction which the rays experience in passing through the atmosphere to the earth's surface. The phenomenon is one of special interest, and various instruments have been devised for its measurement; among which the pyrheliometer of Pouillet, and the actinometer of Herschel, may be mentioned. The observations with these instruments, says Mr. Meech, are certainly valuable and instructive, but, with one very doubtful exception, they fail to exhibit any distinct law. The law of absorption not being obvious directly from observation, the simple hypothesis has generally been adopted that equal thicknesses or strata of the medium absorb equal proportions of the light or heat incident upon each stratum. Lambert, Laplace, Pouillet, and others, have expressed this assumption in an

analytic form, which applies very correctly at higher altitudes and near the zenith. For low altitudes, Laplace combined the same assumption with his theory of refraction, and derived an approximate expression for the relative amounts.

But the inquiry arises how far the fundamental assumption is sustained by experiments. During the trigonometric survey of India, the astronomer, Jacob, observed the extinction of light reflected through an extent of sixty miles of horizontal atmosphere. His results were found to correspond very nearly with the law that "as the first differences of distance increases in arithmetical progression, the intensity of light diminishes in geometrical progression." The experiments of Delaroche and Melloni also indicate that the hypothesis of equal thicknesses absorbing equal portions of the incident heat, is only an approximation, which, in extended media, will differ widely from the truth; indeed, their experiments show an increasing facility of transmission through equal strata in the direction in which the rays proceed.

The necessity of a change, therefore, in the theory of atmospheric absorption to render it conformable to such experiments being obvious, the greater part of Mr. Meech's time available during the past year has been devoted to this object. The remaining discussions relative to the theory of climatic heat, of which this forms a part, are yet in progress. It may here be stated, however, that on computing by this method the observations given in the translation of Kaemtz's Meteorology, p. 150, Mr. Meech shows that out of 100 rays descending vertically from the zenith, 22 rays are lost or absorbed in the atmosphere, and 78 are transmitted to the earth's surface. The same process applied to the mean of observations made with Herschel's actinometer on the Faulhorn and at Brientz, in Switzerland, leads to precisely the same result when reduced to the sea level.

6. A proposition was made to the Institution in 1856 by Dr. James Deane, of Greenfield, Massachusetts, to publish a memoir containing a series of illustrations of his researches relative to the celebrated fossil foot-prints in the sandstone of the Connecticut valley. It is now well established that these foot-prints consist of impressions made by gigantic birds and other animals, and were first brought to the attention of the scientific world by the ardent and persevering efforts of Dr. Deane and the critical investigations of Professor Hitchcock. The number of plates required to illustrate the memoir, as originally proposed, would have involved too great an expense to be met in one or even

two years by the portion of the income of the Institution which could be appropriated to any single publication. It was therefore concluded that Dr. Deane should continue his investigations, and endeavor, by means of photography, to produce representations of all the most important specimens, and that from these a selection should be made sufficient to illustrate the characteristics of the different species of animals by which the impressions had been left. Dr. Deane enthusiastically devoted all the time to this object that he could spare from a laborious practice, on which the support of his family depended, until his career was suddenly terminated by death. To assist in the experiments of photography and in lithographing the illustrations a small appropriation was made, with which about fifty drawings were finished on stone by Dr. Deane himself. The work, however, is in such an unfinished condition that it cannot be published unless some person well acquainted with the subject will undertake the task of its completion.

7. The Annual Report to Congress for the year 1857, together with the appendix, forms a volume of 438 pages. Of this Report the Senate ordered 10,000 and the House of Representatives 7,000 extra copies, of which 5,000 of the first and 2,000 of the latter were given to the Institution for distribution. The volume was restricted in size to 440 pages, and the wood-cuts were furnished, as usual, at the expense of the Smithsonian fund. The statement may be again repeated that the Institution is not responsible for the quality of the paper, nor for all the errors which may be found in the text, since the whole work is set up by a large number of different compositors, and is driven through the press without sufficient time being allowed for revision and proper correction. The distribution, however, of the copies of the Reports has done much to make the Institution favorably known throughout the country. The applications for them are constantly increasing, and even the number liberally furnished by Congress at its last session has been found scarcely sufficient to supply the demand. They are presented to the meteorological observers, and to all libraries and educational establishments. Besides furnishing a kind of knowledge not readily accessible through any other channel, these Reports serve to gratify a laudable public desire for information as to the management and operations of the Institution.

The important truth has now become known in every part of the world, that the property of Smithson was not given for the support of a local establishment, but in trust to the United States for the promo-

tion of knowledge, for the discovery of new truths, and for the diffusion of these among men; that the honor of the government is pledged for the faithful administration of the trust in accordance with the expressed will of the donor, and that consequently every intelligent citizen is interested in all which relates to the administration of the bequest.

8. The collection of the meteorological and physical tables prepared for the Institution by Professor Guyot, has been stereotyped and the first issue has been distributed to the meteorological observers and to foreign institutions. It has been received by the scientific world with warm acknowledgments and special commendation. The Institution has not lost sight of the proposition mentioned in the Report for 1856, to prepare other series of tables for facilitating scientific calculations, and to present in a convenient form the "Constants of Nature and Art." In order, however, fully to realize all the good which will result from this work, it may be necessary to solicit the aid of foreign institutions; and we think it probable that the co-operation of the British Association, as well as that of some of the academies on the continent of Europe, may be secured.

9. Among the miscellaneous publications of the past year should be mentioned a pamphlet, accompanied by a map of the solar eclipse of March 15, 1858, with an account of an instrument by which the latter was projected. This instrument was invented in 1842 by Rev. Thomas Hill, has since been improved, and now affords a ready means of delineating the general phases of an eclipsé, as exhibited over a large portion of the earth, with sufficient accuracy for a first approximation. It consequently saves much labor, and obviates, to a considerable extent, the liability to larger errors in the numerical calculations. The eclipse here mentioned was visible throughout Europe, Greenland, and the North of Africa; also partly visible in the northern part of South America and the eastern part of North America. The map exhibits the time of beginning and ending and the different phases of the eclipse over the greater portion of North America in which there was any probability of observations being made. Unfortunately, however, the face of the sky in the United States on the day of the eclipse was overcast, and few if any observations of value were obtained. The projection of the map, however, illustrates the use of the ingenious mechanical contrivance of Mr. Hill, and will serve to make it generally known to practical astronomers.

10. A new and revised edition of "Directions for Meteorological Observations" has been stereotyped and distributed. To the directions

given in the first edition there have been added instructions for noting periodical phenomena, earthquakes, auroras, &c., and special remarks suggested by the experience of previous years. This publication forms an octavo pamphlet of seventy pages, and is now, perhaps, the most convenient and complete work for the purpose to be found in the English language.

The catalogue of the Dipterous Insects of North America, prepared by Baron Ostensacken, described in the last Report, has been published. It forms an octavo pamphlet of ninety-two pages, and constitutes a portion of a series of works which will be alluded to in a subsequent part of this Report.

11. It was mentioned in the last Report that the Institution had subscribed for a few copies of a treatise on the Fossils of South Carolina, which was commenced by Professors Tuomey and F. S. Holmes, and, after the death of the former, continued by the latter. Copies of five parts of the continuation have been received, and will be distributed in exchange for other works of foreign authors of the same class. This work has been patronized by the State, and is alike creditable to the industry, talents, and knowledge of the author, the skill of the artist, and the intelligent liberality of the government of South Carolina.

Another publication to which a subscription has been made is Peirce's Analytic Mechanics. This is not an elementary compilation, but consists principally of original solutions of many of the most important problems of theoretical astronomy and pure physics. The author at first offered to present this work as a series of memoirs to the Institution, but by means of the subscriptions which have been obtained for it, the publication has since been undertaken by private enterprise. The copies subscribed for by the Institution will be distributed to some of the first class learned societies in Europe, and will doubtless be regarded as an important contribution of new truths, as well as of methods of establishing some of those which have been previously discovered, alike indicative of the genius of the author and of the enlightened and liberal appreciation of the country.

A subscription has also been made for a number of copies, for foreign distribution, of the Mathematical Monthly, edited by J. D. Runkle, of Cambridge, a journal intended to promote the study of mathematics in this country. The plan and execution of this work are such as to commend it to all who are interested in the advance of the important branch of knowledge to which it pertains; and it is gratifying to learn that the patronage which it has received, as well as the number and

character of the articles furnished, are such as to insure its entire success.

12. In accordance with the plan mentioned in the last Report of directing attention to departments of knowledge needing special stimulus, the Institution has made arrangements for the preparation of a series of works on the different orders of insects found in North America, with a view of identifying the species and of systematizing the study of their relations and habits. This is a subject not only of much scientific interest, but also of great practical importance in regard to its connexion with agriculture. When it is considered how much loss is annually caused to this country by the ravages of the Hessian fly, the army and cotton worms, the curculio, the grasshopper, and numerous other species of insects, it must be evident that anything that may tend in however slight a degree to throw light upon the means of preventing such ravages is of great commercial importance. But before we can make use of the experience of other countries on this subject, it will be necessary to identify the insects, since, in regard to them as well as other objects of natural history, the same name is often popularly applied to widely different species.

The greatest deficiency in American natural history is to be found in the department of entomology, there being no original treatise in reference to this country applicable to the wants of the present day. The Institution has therefore made arrangements with eminent entomologists for the preparation of the following series of reports on the different orders, in the form of systematic lists, of all the North American species hitherto described, and an account of the different families and genera, and, whenever practicable, of the species of each order:

Coleoptera, (Beetles, &c.,) by Dr. John L. Le Conte, Philadelphia.
Neuroptera, (Dragon flies, &c.,) by Dr. Hagen, Königsberg.
Hymenoptera, (Wasps, bees, &c.,) by H. De Saussure, Geneva.
Diptera, (Flies, mosquitoes, &c.,) by Baron Ostensacken, of the Russian legation at Washington.
Lepidoptera, (Butterflies, moths, &c.,) by Dr. J. G. Morris, Baltimore, and by Dr. B. Clemens, Easton, Pa.
Hemiptera, (Chinches, roaches, &c.,) by P. R. Uhler, Baltimore.

Catalogues of the Coleoptera and Diptera have been already published, while the descriptions of these orders by Dr. Le Conte and Baron Ostensacken, and of the Neuroptera, by Dr. Hagen, are in an ad-

vanced state of preparation. Moreover, it has been thought desirable as introductions to these catalogues to give an account of the best methods of capturing the insects and preserving them for the cabinet as well as for breeding the larvæ with a view of studying the habits and peculiarities of the species, and with this object arrangements have been made with gentlemen particularly acquainted with different orders for articles relating to them.

A commencement has already been made in the preparation of materials for these works, a part of which will be given in an article to be found in the appendix to this report.

The description of the method of capturing insects and preserving them will be widely distributed, and it is to be hoped that the different correspondents of the Institution interested in this branch of natural history will assist in completing the collections.

Specimens of Neuroptera were last year referred to Dr. Hagen, consisting chiefly of those collected by Captain Pope's expedition, in New Mexico as well as by Baron Ostensacken in the District of Columbia and elsewhere, together with various series from other sources. Three-fourths at least of all the specimens of the collection sent to Dr. Hagen have never before been described. For example, among thirty-four species of *Odonata* (dragon flies) twenty-seven were found to be new. "The materials for study which I have thus received from the Smithsonian Institution," says Dr. Hagen, "are the richest I have ever obtained at one time before."

Meteorology.—The arrangement between the Patent Office and this Institution in relation to the collection of meteorological statistics still continues, and is, we think, producing good results. The number of observers now reporting is about three hundred, and it is only in regard to the want of persistency on the part of some of these that there is room for the expression of regret. Incomplete and irregular records, however, are of importance in furnishing data for the general investigation of the subject—an investigation which is based, as was stated in a former report, upon the preparation of a series of maps of the United States for each day in the year, on which are represented with different colors the portions of the country over which the sky is clear, cloudy, snowing, raining, &c., and, by arrows, the direction of the wind. These maps indicate the place of commencement, the successive stages of development, the changes and the final disappearance of storms. Any person, therefore, who may furnish a daily record of the face of the sky, of the beginning and ending of rain, snow, hail, and

storms, and the direction and intensity of the wind, (which can be done without instruments,) will render valuable service in advancing a knowledge of the laws of the atmospheric disturbances to which we are constantly subjected, and which exercise so important an influence on our health, comfort, and occupation. To induce persons to furnish this simple but valuable information a blank form has been prepared for more general distribution than the one required by those who are provided with instruments. If sufficient data of this kind could be obtained to complete a series of maps, comprising one for each day in a single year, over the whole United States, the laws of the general phenomena of our storms could be determined. For this purpose observations are particularly desirable from regions west of the Mississippi river, and every traveller over the plains would render important service by making a record of the weather at least three times a day, viz: at 7 a. m., 2 and 9 p. m., and transmitting a copy to the Commissioner of Patents. The principles which have been already determined in regard to the development and progress of storms fully demonstrate the importance of the information to be derived from daily telegraphic despatches as regards probable changes of weather in the eastern portions of the United States. The Institution and the public generally are indebted to the Morse telegraph line for the gratuitous reports which its operators have daily furnished.

An object of much interest at the Smithsonian building is a daily exhibition on a large map of the condition of the weather over a considerable portion of the United States. The reports are received about ten o'clock in the morning, and the changes on the maps are made by temporarily attaching to the several stations pieces of card of different colors to denote different conditions of the weather as to clearness, cloudiness, rain or snow. This map is not only of interest to visitors in exhibiting the kind of weather which their friends at a distance are experiencing, but is also of importance in determining at a glance the probable changes which may soon be expected. It is to be hoped that reports may hereafter be received from all parts of the country to which telegraphic lines extend. The value of the information thus received would be much enhanced if a brief record of the direction of the wind and the indications of the thermometer were in all cases added.

At the last meeting of the American Association for the Advancement of Science a committee was appointed, on motion of Major Lachlan, of Cincinnati, to petition the several States of the Union and the governments of other portions of the continent to co-operate with the Smith-

sonian Institution and the Patent Office in establishing systems of stations for observations furnished with standard instruments. Though this committee, consisting of Major Lachlan, Dr. Hough, Professor Coffin, and myself, have not had an opportunity of fully discussing the several points to be recommended, yet it is thought they will adopt the following suggestions, which have been considered and approved by a majority of the members:

1. That stations for observation be established not over sixty miles apart.

2. That at each station the pressure, temperature, and humidity of the air, the direction and velocity of the winds, (both upper and lower currents,) and the kind and amount of cloudiness be observed three times a day—at 7 o'clock a. m., 2 p. m., and 9 p. m.; also the date of the commencement and termination of each rain or snow, with the amount of water that falls, and any other atmospheric phenomena that the observer may deem of interest to note and record.

3. That each station be furnished with a barometer having a zero adjustment, a pair of thermometers carefully compared with each other throughout their entire range, and a rain-gage.

4. That a superintendent be appointed in each State, who shall select the stations and instruments, secure reliable observers, keep himself informed as to the condition of the instruments and observations, and report annually to the legislature of the State, and also to the Smithsonian Institution.

5. That the superintendent be furnished with standard instruments with which the others may be compared when necessary.

6. That these standard instruments be themselves compared with some common standard.

7. That each observer publish his observations monthly in some neighboring newspaper, as an item of local interest, and have, perhaps, five hundred extra slips of the same printed for exchange with other observers; these slips to be sent to the Smithsonian Institution for distribution.

8. That monthly and annual abstracts of these observations be published in a uniform style throughout the United States, and the continent if possible; and that, for the sake of securing such uniformity as well as reducing the cost, they be prepared and published by the Smithsonian Institution, each State contributing a sum sufficient to defray the expense of its own observations; and the whole being combined in a single volume.

9. That each State receive for distribution within its own limits a number of copies of the above-mentioned volume of abstracts, equal to perhaps twenty-five times the number of stations in the State: two for the State library, six for each observer, one for each incorporated college within the State, and the remainder to be distributed at the discretion of the superintendent.

10. That to carry the foregoing provisions into effect, each State appropriate per station $40 for the supply of instruments, and $36 a year afterwards; the latter item to be distributed as follows, viz: $20 to each observer to pay for the printing and postage of the slips containing his monthly observations, $5 per station to the superintendent for his expenses, and $14 per station for preparing and publishing the abstracts.

It gives me pleasure to state that a system of twenty-five stations for minute and accurate observations, with standard instruments, has been established along the northwestern lakes, under the direction of Captain Meade, of the Topographical Engineers, U. S. A. The records are to be made four times a day, and to be reported to the bureau in charge of Colonel Abert, at Washington, and will thus be accessible for investigation by the Institution. In this connexion, I am also pleased to be able to state that the meteorological system contemplated for some years past in Upper Canada has been actually commenced, and that twelve stations have been established at the senior county grammar schools, from most of which reports have been received during the past year. Copies of these observations will be of much value in enabling the Institution to extend the area now included in the field of its meteorological investigations. The report relative to this system presented to the Canadian legislature will be found in the appendix. It is also proper to mention that Doctor Shumard, State geologist, has established a system of stations, furnished with standard instruments, at three important points in Texas. In this he has followed the example of Professor Swallow, who instituted a similar system in connexion with his geological survey of Missouri.

The reductions of all the observations which have been made under the direction of the Institution and the Patent Office are now completed, and will be printed as rapidly as the means necessary for the purpose can be appropriated. A large number of maps have been constructed for the investigation of storms, and considerable additions have been made to the material previously collected relative to the climate of this continent.

One of the most important operations with which the Institution has been connected during the past year is the construction of a map to represent at one view the arable and forest land of the United States. This work has been intrusted to Dr. J. G. Cooper, a young naturalist, who has paid particular attention to botany, has been engaged in government explorations in the western part of the United States, and has critically examined all the authorities to be found on the subject. The facts presented at once to the eye by this map are in striking accordance with the deductions from the meteorological materials which have been collected at this Institution, and serve to place in a clear point of view, the connexion of climate with the natural productions of different parts of the earth.

No appropriation has been made for the last two years for the purchase and distribution of instruments other than rain-gages and thermometers. The attempt to furnish barometers to important stations at a distance has not been successful. In the majority of cases they have been broken before they arrived at their place of destination, and we find from experience that this instrument cannot be safely transported, except by hand or by water.

Magnetic Observatory.—From the date of the last report the declination needle of the magnetic observatory, established at the expense of the Coast Survey and the Smithsonian fund, was in continued operation until October, 1858, when the introduction of a large iron pipe for the supply of the grounds with the Potomac water made a new adjustment of the apparatus necessary, and interrupted the continuity of the record. Up to that time the remaining instruments had not been received from London, though they were ordered by Professor Bache before the erection of the building, several years ago. The delay, we have since learned, was occasioned by death in the family of the inventor, who had kindly undertaken to superintend their construction, and especially to make the adjustments for the compensation for changes of temperature. The instruments have at length been received, and will be put in operation early in the spring of the present year. They were completed and forwarded under the direction of Mr. Charles Brooke, the author of this ingenious and truly valuable mode of automatic registration.

The importance of putting this observatory in full operation will be manifest by a reference to a communication in the appendix to this report from General Sabine to the Secretary, in which it is stated that it is in contemplation to establish similar observatories at Pekin, the

Falkland Isles, Newfoundland, and Vancouver's Island, and in which the hope is expressed that the magnetic observatory on the Smithsonian grounds may be in a condition to co-operate in the efforts that are thus about to be made to determine the laws of the perturbations of the intensity and direction of the magnetic force in a continuous belt encircling the globe.

Laboratory.—During the past year the laboratory has been under the charge of Professor Shaeffer, late of the United States Patent Office, and Dr. Craig, of this city. These gentlemen have reported to the Institution on all articles of public interest which have been referred to them for examination, and have made a series of investigations on a large number of specimens of guano, which were submitted to the Smithsonian Institution by the general government. The policy adopted in regard to the specimens of various kinds referred to the Institution for examination, is to furnish a report free of cost to the parties making the reference, provided the information is of general interest or immediately connected with the advance of science, but if the examination is required principally to promote the interest of individuals or companies, a charge is made sufficient to cover the expense of the investigation. By the adoption of this plan the laboratory is kept in operation by means of a small appropriation for chemicals and apparatus from the Smithsonian fund.

Exchange —The system of international exchanges continues to be highly successful, and the amount of material transmitted abroad and that received in return is constantly increasing. Few, if any, American Institutions publishing transactions or reports have any other means of effecting exchanges with foreign societies, and although the income of the Institution will not warrant a much greater extension of this part of the operations, yet we trust that nothing will interfere to lessen its present efficiency and usefulness.

It will be seen from the report of Professor Baird that during the year there were 913 packages sent abroad by the Institution, weighing 22,674 pounds. The number of parcels received by the Institution from other parties for foreign distribution was 4,425.

Library.—The fact has been repeatedly mentioned in preceding reports that the principal object aimed at in the collection of the library is to procure as perfect and extensive a series as possible of the transactions and proceedings of all the learned societies which now exist or have existed in different parts of the world. It is to works of this character that the student of science is obliged to refer for the minute

history of the progress of any special branch to which he may be devoted, and to ascertain accurately what has been published on his particular subject previous to commencing his own labors, or at least before he gives the results to the world, in order that he may do justice to those who have preceded him in the same path, and have due regard to his own reputation in not publishing facts and principles as new discoveries which have long since been recorded in the annals of science.

Principally by means of the system of exchange, which has been so successfully prosecuted by the Institution, the library is now richer in this class of books than perhaps any other in the country, and every year it is increasing in value, not only from the current publications of the various societies of the world, but by almost constant additions of series and of volumes to complete sets which had before been imperfect.

The value of this library to the country will be much enhanced, first, by the publication of a list or catalogue of the different series of transactions and proceedings of which it is now actually in possession; and secondly, by a general index or list of titles of the various memoirs or papers contained in the whole collection. The first of these objects will soon be accomplished by a complete catalogue of the whole collection, which has been prepared under the direction of Professor W. W. Turner, and is now in the press, and will be distributed to all the correspondents of the Institution in the course of a few months. This catalogue will not only serve to make known to the men of science in this country what the library actually contains in the line of transactions, but will also indicate to the foreign contributors its deficiencies, and thus enable them, from their store of duplicates, to complete imperfect sets, as well as to increase the series.

The second desideratum is one which is felt as such by the whole scientific and literary world, and it will be recollected that in the report for 1855 I mentioned the fact that, in behalf of this Institution, I had addressed a letter to the British Association, setting forth the importance of the publication of a list of the titles of the different memoirs or papers contained in all the transactions of the learned societies of the world, and offering to co-operate in the important enterprise by furnishing a list of the contents of the volumes of transactions and proceedings of the different societies of this country. I am now much gratified in being able to inform the Board of Regents that this proposition was favorably considered by the Association, and

that the great work has actually been commenced at the expense and under the direction of the Royal Society of London. It is estimated that the whole number of titles will amount to 250,000, the cost of printing which will probably exceed even the income of the endowment of the Royal Society; but the hope is entertained that other institutions of Great Britain, as well as those of other countries, will contribute towards defraying the expense.

At the last session of Congress a bill* passed the House of Representatives in reference to the present copyright law, which was in accordance with the views presented in the several reports of the Board of Regents.

The requirement that three copies of every original work secured by copyright should be forwarded to Washington, to be deposited respectively in the Libraries of Congress, the Department of State, and this Institution, has been found as oppressive to the author, in the case of valuable and costly works, as it was burdensome to the libraries intended to be benefited, in the case of trifling and ephemeral ones. The change in the law, by which this requirement will be in future limited to the archives of the Interior Department at the Patent Office, while it affords relief on the one hand, will on the other furnish ample security in case of contested title; and, being more easily and constantly complied with, will insure to those who feel an interest in the progress of American literature at least one entire and connected series of these publications.

The additions to the library of the Smithsonian Institution by exchange during 1858 have been large and important, the total being considerably greater than in 1857. They consist of the following items, viz: 553 octavo volumes, 156 quarto, 14 folio; also, 1,695 pamphlets and parts of volumes, and 122 charts and maps, making in all 2,540; being an excess of 780 volumes and parts of volumes over 1857. Many of the receipts for the year consist of series of transactions of societies more or less complete, tending to add greatly to the resources of the library. Among these may be mentioned the Memoirs of the Academie des Sciences of Dijon, 30 volumes; of the Haarlem Society of Sciences, 41 volumes; of the Royal Netherlands Institute at Amsterdam, 14 volumes quarto; of the Academy of Sciences of Montpelier, 9 volumes quarto; a full series of the publications of the Hydro-

* Since the date of this report, the bill referred to having passed the Senate also, has become a law, and henceforth it will be requisite for the author to deposit only a single copy with the clerk of the district court from whom the certificate of copyright is obtained.

graphical Department of St. Petersburg, in many volumes; the charts of the British Admiralty Board for the year; the Allgemeine Deutsche Bibliothek, in 77 volumes, from the library at Cassel ; the Memoirs of the Landwirthschaftliche Gesellschaft at Klagenfurt, in 14 quarto volumes; and many others.

Alexander S. Taylor, esq., of Monterey, California, sent to the Smithsonian Institution, for examination and use, a manuscript which he had borrowed from the library of the Right Rev. Bishop of Monterey; and of which he gives the following account: "This manuscript containing 94 pages, is a vocabulary of the Mutsun tribe of California Indians, living in the country around the mission of San Juan Bautista, in Monterey county, and now nearly extinct. It was written in 1815, by P. Felipe Arroyo, an old missionary of great natural talents, and, as I am informed, very learned in the Indian languages of this country. He died at the mission of Santa Inez about 1842." This manuscript, on examination, proved of so interesting a character in its relation to American philology and ethnography, that to afford to American scholars opportunities for its study and to lessen the chances of loss of the work, it was thought advisable to have it copied. This accordingly has been done, the labor being performed by a Cuban gentleman, under the supervision of Alexander J. Cotheal, esq., of New York, who has added an English translation of some portions. The number of pages in the transcript corresponds to those of the original. The first seventy-seven pages, after the title and preface, (which, as well as some of the explanatory matter, are in Latin,) are occupied with a collection of Mutsun words and phrases, ranged somewhat irregularly, under the letters of the alphabet, accompanied by a Spanish translation. The Indian words and phrases are written in black, and the Spanish in red ink. The remaining pages contain hymns, prayers, and catechetical exercises composed by the priests, and some specimens of the music used in the native songs and dances. The original, of course, has been returned, and the copy is placed in the library of the Institution.

The extensive alterations in the wing of the building appropriated to the library, mentioned in the last report, have been completed, and the additions have been found not only of importance in the better arrangement and accommodation of a larger number of books, but also in increasing the general architectural effect of the apartment.

Museum.—The portion of the Smithsonian income which can be devoted to a museum, and the $4,000 per annum appropriated by Congress, would not together be sufficient to establish and sustain a general collection of specimens of the natural history of the world. It will, therefore, be the policy of the Institution, unless other means are provided, to confine the collections principally to illustrations of the products of the North American continent. For this purpose efforts have been made, principally through the various exploring expeditions, to obtain a large number of specimens of all the species of the different kingdoms of nature found in North America; and at this time the collection under charge of the Institution is more extensive in number and variety than any other which has ever before been made relative to this portion of the globe. It is not in accordance with the general organization of the Institution to form a museum of single specimens, interesting only for their rareness, but to collect a large number of specimens of each species, particularly of such as have not been described, and to distribute these among the several naturalists who may have the industry, ability, and the desire to study them; the primary object of the Institution, namely, the increase of the existing sum of knowledge in this case, as in all others, being kept prominently in view.

The Institution has now become the curator of the collections of natural history and ethnology of the government, and by law is empowered, as it appears to me, to make the same disposition of the materials contained in these collections as it does of those procured at its own expense; the design will be to render the specimens in the greatest degree serviceable to the advance of knowledge. The museum now consists of the following collections, of which, according to Professor Baird, about one-fifth were brought from the Patent Office:

First, those of the naval expeditions; second, those of the United States geological surveys; third, those of the boundary surveys; fourth, those of surveys for railroad routes to the Pacific; fifth, of miscellaneous expeditions under the War and Navy Departments; sixth, those of miscellaneous collections presented or deposited by societies and individuals; and, lastly, of an extensive series of the results of explorations prosecuted by the Institution itself. By far the greater portion of the whole has been made under the stimulus and immediate direction of the Smithsonian Institution. A number of the special collections are still in the hands of those to whom they were intrusted for scientific investigation and description. The arrangement of the cases

and the disposition of the articles intended for public exhibition has been a subject requiring considerable thought and experiment. It was not only desirable to obtain the largest amount of space for the accommodation of the articles, but, also, to arrange the whole so as to harmonize with the architectural embellishment of the large hall and thus to produce a proper æsthetical effect.

For a particular account of the present condition of the museum, and for a detailed history of the several series of collections of which it is composed, I beg leave to refer to the report of Professor Baird, herewith annexed.

It is proper to add that the Institution continues to be under great obligations to the steamer line to California *via* Panama (consisting of the United States Mail Steamship Company, the Panama Railroad and the Pacific Mail Steamship Company,) for its most generous and liberal aid in carrying packages between New York and the Pacific coast free of all expense. The agents of the line, Mr. I. W. Raymond in New York, and Mr. A. B. Forbes in San Francisco, have also paid particular attention to the secure and certain transmission of these parcels. When it is known that the aggregate amount transported for the Institution during the year has been not far from one hundred packages, embracing valuable Natural History material, and that merely the ordinary expenses of the transit would have been prohibitory of the reception of most of them, some idea may be gathered of the part taken by these companies in the development of the Natural History of the west coast of America. Nor must it be forgotten that the packages carried free of charge by them contain not only specimens of Natural History from the Pacific, but also large numbers of valuable books, presented by or through the Smithsonian Institution, to libraries in California, Oregon and Washington, thus adding greatly to the literary and scientific resources of the west. Hearty acknowledgments are also due for service of similar character to the Pacific Steam Navigation Company, and to the Express Company of Messrs. Wells, Fargo & Co. Mr. Banning, the government freight contractor between Fort Tejon and Los Angelos, has also transported several boxes free of charge.

Gallery of Art.—A large number of portraits, formerly in the Patent Office, of Indian chiefs and a few females of the different tribes which have from time to time visited Washington, which were painted at the expense of government, has been added to the Gallery of Art. These, with the Stanley paintings, now form perhaps the most

valuable collection in existence of illustrations of the features, costumes, and habits of the aborigines of this country.

This gallery is an object of special interest to all visitors to the national metropolis, and to none more so than to the deputations of Indians frequently called to Washington to transact business with the government. A suggestion has been made that there be procured photographic likenesses of individuals of these deputations, with which to increase the number of portraits. It would be a matter regret were the collections ever to be separated, and it is hoped that Congress will in due time purchase the portraits belonging to Mr. Stanley, which will become more and more valuable in the progress of the gradual extinction of the race of which they are such faithful representations.

A number of busts of distinguished individuals, that formed a part of the objects of art at the Patent Office, have also been transferred to the Institution, and although these are not very choice illustrations of sculpture, they serve as a beginning of a collection in this line which may hereafter be worthy of the Institution.

Lectures.—Provision was made for the usual number of popular lectures during the present season, and thus far they have been attended by large audiences. This part of the operations of the Institution, though somewhat restricted in its effects to the city of Washington, has been of considerable importance in awakening a lively interest in the welfare and operations of the Institution on the part of a large number of intelligent and influential gentlemen, who have been invited to lecture, from different and distant sections of the United States. It has likewise been the means of presenting, through the annual report, summaries of particular branches of science interesting to the general reader and of value to the teacher of schools and academies.

It will be recollected that the rooms in the second story of the Smithsonian building are arranged for the accommodation of associations and conventions, of which the following have gladly availed themselves during the past year of the facilities thus offered, namely: The National Medical Association, the United States Agricultural Society, American Pharmaceutists' Association, the National Musical Convention, the Art Association, and the American Colonization Society. The Teachers' Association for the District of Columbia also continues its monthly meetings in one of the apartments.

The influence the Institution is having on the character and reputation of the city of Washington is by no means small. The free

lectures, it is evident, from the interest which they still continue to excite, must tend to promote the intelligence and morality of the citizens, and the various scientific operations which are carried on in connexion with the Institution diversify the objects of interest to the public generally in what pertains to the national metropolis. The following is a list of the lectures delivered at the Institution during the winter of 1858–'59:

Two lectures by Dr. John Rae, of Canada, on "Arctic Explorations and the Probable Fate of Sir John Franklin."

One lecture by J. G. Saxe, esq., of Vermont, on "Poetry and Poets."

One lecture by Professor G. W. Greene, of New York, on "The Artistic Life of Thomas Crawford."

One lecture by Professor J. D. Dana, of Yale College, on "Coral Islands."

Two lectures by Thomas Clemson, esq., of Maryland, on "Water" and "Nitrogen."

Two lectures by Professor P. A. Chadbourne, of Williams College, on "Natural History as related to Intellect, Taste, and Wealth."

Four lectures by Rev. H. J. Comingo, of Ohio, on "Rome, its Historical Reminiscences; its Antiquities and Ruins; its Architectural Monuments; its Fine Arts."

Four lectures by Professor A. Caswell, of Brown University, on "The Magnitude and Figure of the Earth;" "The Law of Gravitation;" "The Dimensions of the Solar System, or the Extent of our Knowledge of Planetary Distances;" and "Sidereal Astronomy."

Five lectures by Professor J. P. Cook, of Harvard College, on "Atmospheric Air," "Oxygen and Ozone," "Nitrogen," "Water," "Carbon," &c., &c.

The lectures of Professor Caswell will be inserted in the Appendix to this report, and, it is believed, will be found interesting to the teacher, as well as to the general reader, on account of the information given relative to many points not usually dwelt upon in popular works on the subject.

Respectfully submitted.

JOSEPH HENRY.

APPENDIX TO THE REPORT OF THE SECRETARY.

Smithsonian Institution,
Washington, December 31, 1858.

Sir: I have the honor herewith to present a report, for 1858, of the operations you have entrusted to my charge, namely, those which relate to the printing, to the exchanges, and to the collections of natural history.

Very respectfully, your obedient servant,

SPENCER F. BAIRD,
Assistant Secretary Smithsonian Institution.

Joseph Henry, L. L. D.,
Secretary Smithsonian Institution.

PUBLICATIONS.

The publications of the Institution during the year are as follows:

Annual Report of the Board of Regents for 1857. One volume, 8 vo., pp. 438.

Catalogue of the Described Diptera of North America, prepared for the Smithsonian Institution by R. Osten Sacken. 8vo., pp. 112.

Map of the Solar Eclipse of March 15, 1858, by Rev. Thomas Hill, of Waltham, Massachusetts. 8vo., pp. 8.

Directions for Meterological Observations and the Registry of Periodical Phenomena. 8vo. pp. 70.

Tables, Meteorological and Physical, prepared for the Smithsonian Institution, by Arnold Guyot. 8vo. pp. 634.

Nereis Boreali Americana, or Contributions to a History of the Marine Algae of North America, by William Henry Harvey, M. D., M. R. I. A. Part III, Chlorospermeae. 4to, pp. 142, and fourteen plates.

Magnetical Observations in the Arctic Seas, by Elisha Kent Kane, M. D., United States navy, reduced and discussed by Charles A. Schott. 4to. pp. 72, and two plates.

A Grammar and Dictionary of the Yoruba Language, by the Rev. T. J. Bowen. 4to. pp. 232.

The following publications are in an advanced state and will be completed early in the year:

Catalogue of Transactions and Periodicals in the Library of the Smithsonian Institution. 8vo.

Catalogue of North American Birds, by S. F. Baird.

EXCHANGES.

The system of international exchanges organized by the Smithsonian Institution a few years ago continues to be highly successful, and is rapidly developing to an enormous magnitude. Every year witnesses a great increase in the amount of material transmitted abroad and received in return, and it is not too much to say that any abrupt termination of the undertaking on the part of the Institution would be felt as a great public calamity. Few, if any, American institutions of note, publishing transactions or reports, have any other medium of exchanging them with foreign correspondents.

The details of operations in this department will be found in the following tables, all of which exhibit a marked increase as compared with 1857:

A.—*Receipt of books, &c., by exchange in* 1858.

Volumes—Octavo	553	
Quarto	156	
Folio	14	
		723
Parts of volumes and pamphlets:		
Octavo	1,187	
Quarto	451	
Folio	57	
		1,695
Maps and charts		122
Total		2,540

B.

Table showing the statistics of foreign exchanges of the Smithsonian Institution in 1858.

Agent and country.	Number of addresses.	Number of packages.	Number of boxes.	Bulk of boxes in cubic feet.	Weight of boxes in pounds.
1. Dr. Felix Flugel, *Leipsic.*					
Sweden	10	14			
Norway	4	7			
Denmark	6	10			
Russia	23	30			
Holland	18	25			
Germany	200	310			
Switzerland	19	27			
Belgium	9	17			
Total	289	440	28	336	11,060
2. H. Bossange, *Paris.*					
France	78	122			
Italy	37	64			
Portugal	2	5			
Spain	5	8			
Total	122	199	11	132	4,525
3. H. Stevens, *London.*					
Great Britain and Ireland	96	250	17	204	6,445
4. *Rest of the world.*	18	24			644
Total	525	913	56	672	22.674

C.—*Packages received by the Smithsonian Institution for foreign distribution in* 1858.

	No. of packages.
Albany, N. Y.—	
New York State Agricultural Society	20
Boston, Mass.—	
American Academy of Arts and Sciences	251
Boston Society of Natural History	36
Public Library of City of Boston	3
Cambridge, Mass.—	
American Association for Advancement of Science	64
Cambridge Observatory	139

	No. of packages.
Charleston, S. C.—	
Prof. F. S. Holmes	2
Chicago, Ill.—	
Col. J. D. Graham, U. S. A.	188
Cincinnati, Ohio.—	
Dr. M. L. Knapp	6
Columbia, Mo.—	
Prof. G. C. Swallow	20
Columbia, Pa.—	
Prof. S. S. Haldeman	1
Georgetown, D. C.—	
Georgetown College	5
New Haven, Conn.—	
American Journal of Science	16
American Oriental Society	9
W. P. Blake	14
Prof. J. D. Dana	6
Yale College	4
Philadelphia, Pa.—	
Academy of Natural Sciences	151
American Philosophical Society	41
Central High School of Philadelphia	100
Historical Society of Pennsylvania	52
Isaac Lea	47
C. M. Wetherill	22
Providence, R. I.—	
State of Rhode Island	10
St. Louis, Mo.—	
St. Louis Academy of Sciences	141
Dr. B. F. Shumard	8
Toronto, Canada.—	
Canadian Institute	4
Washington, D. C.—	
U. S. Patent Office	1,403
U. S. Coast Survey	919
National Observatory	73
Secretary of War	360
Surgeon General	300
Capt. Charles Wilkes	10
Total	4,425

D.

Addressed packages received by the Smithsonian Institution from Europe for distribution in America in 1858.

	Number of packages.
Albany, N. Y.—	
New York State Library	18
New York State Agricultural Society	7
New York State Medical Society	1
Amherst, Mass.—	
Amherst College	11
Ann Arbor, Mich.—	
Observatory	10
Boston, Mass.—	
American Academy of Arts and Sciences	59
Boston Society of Natural History	46
Bowditch Library	10
Historic Genealogical Society	2
Statistical Society	10
Bowdoin, Me.—	
Bowdoin College	8
Cambridge, Mass.—	
American Association for Advancement of Science	12
Cambridge Astronomical Journal	9
Cambridge Observatory	27
Harvard College	22
Professor L. Agassiz	16
Professor Asa Gray	13
Professor Peirce	11
Charleston, S. C.—	
Elliott Society of Natural History	8
Cincinnati, Ohio.—	
Observatory	10
Columbia, Mo.—	
Professor G. C. Swallow	5
Columbus, Ohio.—	
Ohio State Board of Agriculture	22
Dartmouth, Me.—	
Dartmouth College	26
Georgetown, D. C.—	
Georgetown College	22
Lansing, Mich.—	
Michigan State Agricultural Society	17
Madison, Wis.—	
Wisconsin State Agricultural Society	25
Historical Society of Wisconsin	4
New Haven, Conn.—	
American Journal of Science	17
American Oriental Society	5
Professor J. D. Dana	19
Yale College	8
New Orleans, La.—	
New Orleans Academy of Natural Sciences	23
New York.—	
American Geographical and Statistical Society	29
New York Lyceum of Natural History	38
American Ethnological Society	3

D—Continued.

	Number of packages.
New York—Continued.	
New York University	7
Philadelphia, Pa.—	
Academy of Natural Sciences	86
American Philosophical Society	65
Central High School of Philadelphia	1
Pennsylvania Institute for the Blind	11
Wagner Free Institute	4
Isaac Lea	8
Dr. John L. Le Conte	4
Dr. Joseph Leidy	12
Providence, R. I.—	
Brown University	5
San Francisco, Cal.—	
California Academy of Natural Sciences	17
St. Louis, Mo.—	
St. Louis Academy of Sciences	26
Santiago, Chili.—	
University of Chili	6
Springfield, Ill.—	
Illinois State Agricultural Society	1
Washington, D. C.—	
United States Patent Office	68
Ordnance Bureau	3
United States Coast Survey	41
National Observatory	73
Secretary of War	3
National Institute	2
State Department	1
Congress Library	15
Lieutenant J. M. Gilliss, United States navy	16
West Point, N. Y.—	
Military Academy	3
Worcester, Mass.—	
American Antiquarian Society	6
Miscellaneous institutions	261
Miscellaneous individuals	221
Total	1,539

MUSEUM.

Additions to the museum.—Independently of the collections of the Patent Office, transferred in 1858, and of which a more detailed notice will be found on another page, the additions to the Smithsonian museum during 1858 have been of great magnitude and importance, in many respects exceeding those of any previous year, occupying, as they did, more than 200 boxes, 20 kegs or barrels, and numerous single packages of greater or less size. It is impossible within my present limits to mention the contents of these in detail, and a general

statement at the end of this report is all that can be given for most of them. A portion, however, of the collections received belong to public or private explorations of such interest as to require a further notice.

EXPLORATIONS UNDER THE WAR DEPARTMENT.

1. *Exploration of the valley of the Platte river, especially of the Loup Fork, under Lieutenant Warren, U. S. A.*—This exploration was conducted in 1857, but the collections (filling 21 boxes) did not reach Washington until 1858. The chief features of the collections consisted of the fossil remains of animals and plants, gathered by Dr. Hayden, geologist of the expedition; but a large and valuable series of recent species was also procured, embracing several new to science.

2. *Exploration of the Colorado river of California, under Lieutenant J. C. Ives, U. S. A.*—Dr. J. S. Newberry, geologist and botanist, Mr. B. Mollhausen, artist and zoologist. Large collections were made in all departments on the Colorado and across to Albuquerque.

3. *Wagon road over the 35th parallel, under Lieutenant Beale.*—A valuable geological collection was made by this party.

UNDER THE STATE DEPARTMENT.

4. *Survey of the northwest boundary, under Archibald Campbell, esq.*—Dr. C. B. Kennerly, surgeon and naturalist, George Gibbs, geologist. The collections of animals and plants, minerals and fossils, made on Puget Sound and on the boundary line, were very full.

UNDER THE NAVY DEPARTMENT.

5. *Survey of the Atrato ship canal route of the Isthmus of Darien, by Lieutenant Craven, U. S. N., and Lieutenant Michler, U. S. A.*—The natural history operations were conducted by Mr. Schott, assisted by Wm. S. and Charles Wood, under the supervision of Lieutenant Michler. A valuable collection of animals and plants of the Isthmus was brought back by this party.

UNDER THE INTERIOR DEPARTMENT.

6. *Wagon road construction through the South Pass, under Wm. M. Magraw.*—This expedition was fitted out in the spring of 1857, with Dr. J. G. Cooper as surgeon, and Mr. C. Drexler as hospital steward and taxidermist. Dr. Cooper returned to Washington before the beginning of the year, bringing large collections with him. Mr. Drexler continued with Mr. Magraw's party, and wintered on Wind river. In March he crossed to Camp Scott, near Fort Bridger, where, remaining until June, he made a very extensive collection of birds, illustrating very fully the ornithology of the Rocky mountain region, and throwing much light on the geographical distribution of the species. His success in this was mainly due to the protection and aid afforded by General A. E. Johnston, in command of the forces, by whose direction every facility was afforded him.

EXPLORATIONS UNDER THE AUSPICES OF THE SMITHSONIAN INSTITUTION.

7. *Exploration of the vicinity of Fort Tejon, California, by Mr. John Xantus.*—During the year 1858 a natural history exploration, commenced in 1857, has been nearly completed by Mr. Xantus, while connected with the military post at Fort Tejon, which, for extent and thoroughness, has perhaps scarcely a parallel on our continent, considering the fact that it was made in about sixteen months by one person, almost constantly occupied in official duties, and under various discouragements. The collections of Mr. Xantus filled 24 large boxes, and included nearly 2,000 birds, 200 mammals, many hundreds of birds' nests and their eggs, with large numbers of reptiles, fishes, insects, plants, skulls, skeletons, &c., all in the highest condition of preparation and preservation, and furnishing such accurate and detailed information of the zoology and botany of Fort Tejon as we possess of but few other points in the United States. Mr. Xantus also made copious notes of the habits and characters of the species, with numerous drawings.

8. *Other points on the west coast.*—Valuable collections from the vicinity of Fort Umpqua, Oregon, have been received from Dr. Vollum, from about San Diego, made by A. Cassidy, and from Monterey, made by A. S. Taylor. A collection of shells, &c., made by Captain Stone in the Gulf of California, assisted by Mr. Sloat, has supplied the first specimens ever received from that region, proving of great interest. Mr. James Wayne has also furnished important collections from the Columbia river.

9. *Rocky mountains.*—A collection of birds from Cantonment Burgwyn, sent in by Dr. W. W. Anderson, has added a new species of birds to our fauna. Interesting collections of mammals and birds from Fort Massachusetts were also made and presented by Captain A. W. Bowman and Dr. McKee. Captain Marcy, in collecting specimens of the *Lagopus leucurus*, or white tailed ptarmigan, has added to the fauna of the United States an interesting species of bird hitherto only found in British America.

10. *Other regions of North America.*—Additional collections of the animals of the Red River of the North have been received from Mr. Donald Gunn, and of Texas, from Major G. H. Thomas. Mr. Thos. E. Blackney, of Chicago, has contributed one of the few specimens of whooping crane (*Grus americana*) found in collections. The collections of Florida animals by Mr. Gustavus Wurdemann, made in continuation of previous years, have been very valuable, adding, as they have done, several new species of birds, reptiles, and invertebrates to our fauna; collections made in northern Wisconsin by Mr. Kennicott, and in many other regions by contributors, mentioned in detail in the alphabetical list at the end of this report, have also been of much value.

11. *Other parts of the world.*—The exotic additions consist chiefly of collections made in the Sandwich Islands by Mr. W. H. Pease, and on the Isthmus of Panama by Captain J. M. Dow and the Rev. Jos. Rowell.

12. *Astronomical expedition to Peru.*—The expedition to Peru, for the purpose of observing the total eclipse of the sun of September, 1858, by Lieutenant Gilliss, United States navy, under the auspices of the Smithsonian Institution, was accompanied by Mr. Carrington Raymond, who made such collections of birds, reptiles, and fishes as his time and opportunities would allow, and succeeded in obtaining several species not previously in the collection.

Among the collections received during the year, not strictly made by single expeditions or individuals, one presented by the Museum d'Histoire Naturelle of Paris deserves especial mention. This consists of the types of many of the genera of serpents described by M. Duméril, selected with special reference to American forms. A labelled collection of land shells from Mr. Binney, and of rare eggs of North American birds from Mr. John Krider, are also worthy of particular notice.

PRESENT CONDITION OF THE MUSEUM.

The museum of the Smithsonian Institution, as at present constituted, has been supplied with materials chiefly from the following sources:

First. The collections brought from the Patent Office, and made up principally of the results of various explorations. They are as follows:

1. United States exploring expedition, under Captain Wilkes, United States navy, 1838–1842. The collections made by this naval expedition are supposed greatly to exceed those of any other of similar character ever fitted out by a foreign government, no published series of results comparing at all in magnitude with that issued under the direction of the Joint Library Committee of Congress.*

The collections made embrace full series of the animals, plants, minerals, and ethnological material of the regions visited, such as the coasts of South America, the islands of the South Seas, &c.

2. Exploration of the Amazon and its tributaries, by Lieutenant

* The following reports relating to the operations and collections of the expedition have been published or are in press, the text in quarto, the plates in folio:

1. Narrative of the expedition by Captain C. Wilkes, 5 vols. text, one of plates.
Zoophytes. By Prof. J. D. Dana, 1 vol. and atlas.
Geology and Mineralogy. By Prof. J D. Dana, 1 vol. and atlas.
Crustacea. By Prof. J. D. Dana, 2 vols. and atlas.
Philology. By Mr. Hale, 1 vol.
Races of Man. By Dr. C. Pickering, 1 vol.
Geographical Distribution of Species. By Dr. C. Pickering, 1 vol.
Mammals and Birds. By T. R. Peale, 1 vol.
Mammals and Birds, 2d edition. By J. Cassin, 1 vol. and atlas.
Meteorology. By Captain Wilkes, 1 vol.
Shells. By Dr. A. A. Gould, 1 vol. and atlas.
Reptiles. By Dr. C. Girard, 1 vol. and atlas.
Ferns. By Mr. Breckenridge, 1 vol. and atlas.
Botany. By Dr. Gray, 2 vols. and atlas.
Botany of Western America. By Dr. Torrey, 1 vol. and atlas.
Mosses. By Mr. Sullivant, 1 vol. and atlas.
Fungi. By Messrs. Berkeley and Curtis, 1 vol. and atlas.
Algae. By Prof. Bailey, 1 vol. and atlas.
Charts. 2 vols. folio.

In addition to these, the report on the fishes, by Professor Agassiz, is stated to be nearly ready for the press.

W. E. Herndon, United States navy. These consist chiefly of vertebrate animals and ethnological material.

3. Exploration of the valley of Great Salt Lake, by Captain Stansbury, United States army. Collections in character much like the last.

4. Exploration of the Zuñi and Colorado rivers by Captain Sitgreaves, United States army, and the survey of the Creek Boundary by Captains J. C. Woodruff and Sitgreaves.

5. Presents made to the United States by the King of Siam and other foreign governments, deposited by the State Department.

6. Collections of Commodore M. C. Perry, United States navy, made while negotiating a treaty with Japan, and the presents to the United States government through him from the Japanese authorities.

7. Collections made by Dr. D. D. Owen in his United States geological explorations in the west.

8. Collection of birds, &c., of British Guiana, from Rev. C. W. Denison.

9. African curiosities, deposited by Rev. Dr. Gurley, in behalf of the American Colonization Society.

10. Miscellaneous specimens belonging to the old Washington Museum and deposited by Mr. John Varden.

11. Miscellaneous specimens, including paintings and statuary, from different individuals, presented to or deposited in the national gallery.

12. Collection of Indian paintings from the War and Indian Departments.

In addition to the collections above enumerated, the old hall contained numerous specimens of different kinds belonging to or deposited in the care of the National Institute. These the Smithsonian Institution offered to take charge of, subject to such future order as the National Institute might make in regard to them, but the offer was declined at the time by its authorities and the specimens were left in their places, but afterwards concentrated in several of the old cases of the Patent Office hall. As no supervision is now exercised over them it is much to be feared that great injury will necessarily result to the more perishable portions.

Second. The collections in the Smithsonian Institution belonging to the United States, and deposited in pursuance of the act of incorporation, other than those mentioned, are as follows:

13. Collections of the United States geological survey made in Iowa, Illinois, and Minnesota, under Dr. D. D. Owen.

14. Collections made on Lake Superior, by Messrs. Foster and Whitney.

15. Collections made by Dr. Charles T. Jackson.

16. Collections made in Oregon and Washington Territories, by Dr. J. Evans.

17. Collections of vertebrates and minerals of Chile, made by Lieutenant J. M. Gilliss, U. S. N.

18. General collections made by the North Pacific surveying and exploring expedition under Captains Ringgold and Rodgers, U. S. N., chiefly in the China Seas, Behring Straits, Coast of California, &c.

19. General collections made by the United States and Mexican

boundary survey, under Colonel Graham and Major W. H. Emory, U. S. A.

20. General collections made by the Pacific railroad survey of the 47th parallel, under Governor Stevens.

21. General collections made by the Pacific railroad survey on the 38th, 39th, and 41st parallels, under Captains Gunnison and Beckwith.

22. General collections made by the Pacific railroad survey on the 35th parallel, under Captain Whipple.

23. General collections made by the Pacific railroad survey on the partial route in California, under Lieutenant Williamson.

24. General collections made by the Pacific railroad survey on the western end of the 32d parallel, under Lieutenant Parke.

25. General collections made by the Pacific railroad survey on the eastern end of the same parallel, under Captain Pope.

26. General collections made by the Pacific railroad survey in California and Oregon, under Lieutenant Williamson.

27. Collections made by Captain Pope while sinking artesian wells on the Llano Estacado.

28. Collections made by the northwestern boundary survey, under A. Campbell, esq.

29. Collections made in Paraguay, by Captain Page.

30. Collections made on the Isthmus of Darien, by Lieutenant Michler, U. S. A.

31. Collections made by Lieutenant Bryan during two seasons spent in constructing a wagon road from Fort Riley to Bridger's Pass.

32. Collections made on the Upper Missouri and Yellowstone, under Lieutenant Warren.

33. Collections made on the Platte, by Lieutenant Warren.

34. Collections made on Red river, by Captain Marcy.

35. Collections made by the South Pass wagon-road expedition, under W. M. Magraw.

36. Collections made during the exploration of the Colorado river, under Lieutenant Ives.

For an account of the many private collections presented to the Smithsonian Institution, reference must be made to the annual reports of 1850—1857, and to another portion of the report for the present year; several, however, need special mention here on account of their extent and value.

37. Collections made in northern Mexico, by Dr. Berlandier, purchased and presented by Lieutenant Couch, in addition to a similar collection made by himself.

38. Collections made in Texas, Louisiana, and Florida, by Mr. Gustavus Wurdemann.

39. Collections made on the Pacific coast, by Lieut. Trowbridge.

40. Collections made in Washington and Oregon Territories, by Dr. George Suckley.

41. Collections made in Washington, California, and Nebraska, by Dr. J. G. Cooper.

42. Collections made at Petaluma, California, by Mr. E Samuels.

43. Collections made on the Upper Missouri, by Thaddeus Culbertson; and others made by Dr. Hayden and Colonel A. J. Vaughan, Indian agent for the Blackfeet.

44. Collections made at Fort Tejon, Cal., by Mr. John Xantus.
45. Collections made in Wisconsin and Missouri, by Dr. P. R. Hoy.
46. Collections made in Wisconsin, by Rev. A. C. Barry.
47. Collectious made in Illinois and Minnesota, by Robert Kennicott.
48. Collections made on the New England coast, by W. Stimpson.
49. General collections, deposited by S. F. Baird.

Together with very many others of greater or less note.

As the result of combining all the collections referred to in the preceding notices, it may be said that the museum of the Smithsonian Institution is entitled to no mean rank among similar establishments elsewhere. It is certainly superior to any other in the United States as a general collection, although in the specialities of exotic birds, shells, fossils, and minerals it is surpassed by the Philadelphia Academy of Natural Sciences. The material is not even now wanting to give it a first class position; only the means to properly determine, arrange, and exhibit the collections already within the walls of the Institution. With the enormous amount of duplicates of rare and new species on hand, it will be possible, after the determinations have been completed, to make additions by exchange to any conceivable extent, almost without the expenditure of a single dollar in the way of purchase. It must be remembered, too, that the collections in the building have been made since 1850, (with the exception of most of those brought from the Patent Office, which hardly form one-fifth part of the whole museum,) and that the additions of the past year, independently of those just mentioned, have exceeded those of any previous one.

There are many departments of natural history in which the collections of the Smithsonian Institution are believed to be superior to any others extant, not merely to those of the United States. In all that relates to North America, and perhaps to South America, also, it has no equal anywhere. The collection of crustacea of the world is said to be superior even to that of the Paris museum; and the same may, possibly, be said of the recent corals. And yet no special attempts have been made to this end. With the general interest of Americans in such subjects, nothing would be easier than to excite the zeal of officers of the naval and mercantile marine, government officials abroad, and travellers, to such a pitch as to yield vast results every year. Unfortunately the Smithsonian Institution has neither space for such extensive exotic collections nor funds to devote to their preparation and arrangement, all the appropriation of Congress being required for the preservation of the specimens belonging to the United States, and for the arrangement and exhibition of the contemplated North American museum. This latter it is proposed to make as complete as possible, so as to exhibit to visitors from all parts of the Union a full series of natural objects belonging to each State.

In view of the importance of having some one public museum, illustrating as fully as possible the natural history of the world, and taking rank with those of London, Paris, Berlin, Vienna, and others, and considering that so excellent a foundation has already been laid by the collections now in the Smithsonian Institution, and the ease

with which they may be augmented to any desirable extent, it is earnestly to be hoped that the day is not far distant when the moderate amount of funds necessary may be placed in the hands of this Institution.

It is, of course, impossible, in a few words, to give a detailed account of the collections of the Smithsonian museum. This can only be supplied by the descriptive catalogues of species and specimens already published or now in course of preparation, after the plan of those of the British museum. These will serve not only as guides to the cases and collections, but as manuals by which the same species may be readily identified elsewhere.

Work done in connexion with the collections.

The chief labor of the year in reference to the museum has consisted in the transfer and partial arrangement of the collections belonging to the United States, for many years constituting the national gallery of the Patent Office, at first under the direction of the Joint Committee of the Library of Congress, but for some years under that of the Commissioner of Patents.

In the spring of 1857 the appropriation was made by Congress for the construction of cases in the Smithsonian building for the reception of the Patent Office collections, but owing to various drawbacks these cases were not entirely finished until 1858. As soon as the various technicalities incident to the transfer of this property were completed, the work of removal was commenced and the whole collection moved over in July last. Since that time much has been accomplished towards giving to the different portions of the collections thus transferred their final arrangement, but much necessarily remains to be done before this can be completed. An indispensable preliminary consists in the entry of every specimen in its appropriate record book and the ineffaceable attachment of a number, by means of which the displacement or loss of a label (so likely to occur in the operations of a large and growing museum) will be of comparatively little consequence. The next step is to post all the specimens of each species on its appropriate invoice sheet, as fast as accurate identification is accomplished, and after these sheets are systematically assorted the final arrangement of the specimens themselves can then be completed and catalogues printed as guides to the collection.

As none of these details had been entered into with regard to the Patent Office collections previous to their removal, (with the exception of the labelling of a portion, and the entry of the crustacea in a record book,) it becomes necessary to carry them out in the Smithsonian Institution. This, however, will require a long time to complete, owing to the magnitude of the undertaking, and in the mean time the specimens exhibited have been provisionally arranged for the present, to be systematically placed and accurately and legibly labelled hereafter. This has already been done by Mr. Varden for the ethnological collections in the galleries of the west end of the hall, and by Professor Dana for the corals.

Considerable progress has been made in recording, determining, and invoicing the other collections in the Institution, apart from those brought from the Patent Office. The mammals, North American birds and their eggs, the osteological collection, and the North American lizards, are at present so well posted up that the number of species represented in the different series, with the aggregate number in each series, the locality, donor, and other incidents of all the specimens of each can be shown at a glance. Nearly all the North American reptiles, other than saurians, are entered, and many of them determined; and the same may be said of the western fishes. The following table will show how much of this labor of recording has been done in 1858.

Table exhibiting the entries in the record books of the Smithsonian museum in 1858, *in continuation of previous years.*

	1851.	1852.	1853.	1854.	1855.	1856.	1857.	1858.
Mammals	------	114	198	351	1,200	2,046	3,200	3,226
Birds	------	------	------	4,353	4,425	5,855	8,766	11,390
Reptiles	------	------	------	------	------	106	239	4,370
Fishes	------	------	------	------	------	155	613	1,136
Skeletons and skulls	911	1,074	1,190	1,275	2,050	3,060	3,340	3,413
Crustacea	------	------	------	------	------	--------	--------	939
Eggs of birds	------	------	------	------	------	--------	--------	1,032
Total	911	1,188	1,388	4,979	7,675	11,222	16,158	25,506

The actual number of entries during the year amounts to 9,348, being the difference between the aggregates of 1858 and 1857. As most of these, however, have been made at least twice in the record book and on the invoices, the total is nearer 18,000.

From the preceding table it will be seen that the entries already exceed twenty-five thousand. In the case of alcoholic series, however, each bottle, though containing only one species from one locality, may, and almost always does, include more than one specimen, the average being at least five, which would give to the reptiles and fishes an addition of 22,024 pieces, which would bring the number of registered specimens nearly to forty-eight thousand. This is, however, far from expressing the full statistics of the collection, as there are at least ten thousand jars of alcoholic specimens not yet entered, to say nothing of the exotic birds and other objects.

During the year the determination of the North American birds in the Smithsonian collection has been completed, and the results presented by myself in the ninth volume of the reports of the Pacific railroad survey, occupying over a thousand quarto pages. The description of each species is followed by a list of all the specimens in the collection, with an indication of the locality, collector, date, and other details, and the report in question thus serves as a catalogue of the ornithological collections of the Institution, as the previous volume (eighth) did of its North American mammals. From this report it

will be seen that the number of known North American species of birds amounts to nearly 720, or about 225 more than given in 1844 by Mr. Audubon, and that nearly all are in the Smithsonian collection.

The North American eggs and nests have been determined and arranged in the hall, where they form a highly attractive feature. The North American saurians have also been monographed and described in detail to the number of about 90 species. This work is still in manuscript. Much progress has also been made in a similar memoir on the serpents, with the assistance of Mr. Kennicott. Detailed accounts of the fishes collected by the Mexican boundary and Pacific railroad surveys, as also of the reptiles of the United States exploring expedition, prepared by Dr. Girard, have been published in their several reports.

Other collections belonging to the Smithsonian museum, in process of elaboration during the year, are as follows:

Birds.—The report of Mr. Cassin on the birds of the United States exploring expedition has been printed during the year. The same gentleman has now the birds collected by Captain Page in Paraguay, and those of the North Pacific expedition, and has nearly completed reports upon them.

Reptiles.—The collection of North American turtles was placed some years ago in the hands of Professor Agassiz, from whom a detailed account of them may shortly be expected. Dr. Hallowell has furnished during the year a report on the reptiles of the North Pacific expedition.

Fishes.—The fishes of the United States exploring expedition are in the hands of Professor Agassiz for the preparation of a report, to be published in the series of the expedition. The collection contains many hundreds of new species. The fishes collected during the North Pacific surveying and exploring expedition, under Captains Ringgold and Rodgers, are in the hands of Mr. J. C. Brevoort.

Invertebrates.—Mr. Stimpson has been occupied during the year in investigating the crustacea collected by him on the North Pacific exploring expedition. Dr. A. A. Gould has also had in hand the shells, and Mr. Barnard the echini of the same expedition. The Neuroptera of the Smithsonian museum are in progress of examination by Dr. Hagen, of Königsberg, the Coleoptera by Dr. Le Conte, the Hymenoptera by Mr. De Saussure, the Diptera by Baron Osten-sacken, the Hemiptera by Mr. Uhler.

Plants.—Large collections of plants collected by government expeditions are still in the hands of Drs. Torrey and Gray, Mr. Sullivant, Mr. Curtis, and others.

Geological Collections.—The collections made during Lieutenant Warren's explorations of the Upper Missouri region have been in progress of investigation during the year by Messrs. Hayden and Meek, and those of Lieutenant Ives' expedition to the Colorado by Dr. Newberry.

Besides the scientific details connected with the administration of the Smithsonian museum and collections, much has been done in regard to the mechanical portion, in addition to the more or less complete arrangement of the Patent Office series. A beginning has been made in the cleaning of the mounted animals belonging to the

Patent Office collection, which had become greasy, dusty, or distorted, by time and accident, and by their transfer to new stands. Many skins of mammals and birds have been mounted and placed in the cases to supply deficiencies, or to replace defective specimens, although a vast amount yet remains to be accomplished in this respect before the collection will attain its proper condition. A large number of skulls have been cleaned and put in place; nearly all the jars of alcoholic specimens in the building, amounting to over 15,000, have been washed and replaced with fresh spirits; more than 1,000 gallons of alcohol having been required for this purpose.

Distribution of Collections.

As the collections of the Smithsonian Institution become properly indentified the duplicates are laid aside to be distributed to other parties. It would, of course, be manifestly inexpedient to make such distribution before determining the species accurately, as nearly all are referred to in some official report or special monograph, and the duplicates will be chiefly valuable as the types of such works. For this reason not much has yet been done in the way of distribution to public museums, although materials are constantly being furnished to men of science for monographic investigations.

Even after the species may have been determined some time must elapse before any extensive systematic distribution of series can be effected, as the labor of labelling each specimen, making duplicate catalogues, and of packing, will be very great. No time will be lost, however, in doing whatever is possible in the case, not only for the purpose of supplying a great want, but also of relieving the shelves and cases of the Institution of a redundancy of material.

LIST OF DONATIONS DURING 1858.

Dr. W. W. Anderson, U. S. A.—Birds of New Mexico.

Samuel Arny.—Reptiles from Kansas.

Dr. W. O. Ayres.—Fishes from California.

A. S. Babcock.—Eight skins of birds of Massachusetts.

Wm. M. Baird.—Coal from Pittston, Pa.

Thos. Barnet.—Cast of mastodon tusk (perfect) from St. Thomas, Canada West.

Sidney Barnet.—Box of minerals from Egypt.

Dr. J. B. Barratt.—Skin of *Pityophis melanoleucus* from South Carolina, and *Lepidosternon floridanum*, in alcohol.

Lieutenant Beale.—Four boxes of geological collections, with some birds and alcoholic specimens.

Thos. E. Blackney.—Mounted *Grus americana* from Illinois.

W. P. Blake.—Zoological collections from New Mexico.

W. G. Binney.—Series of land shells of United States.

Captain A. H. Bowman, U. S. A.—Mammals and birds of New Mexico.

J. Brakely.—Jar of mammals from New Jersey.

J. L. Bridger.—Wasp nests and alcoholic collections from North Carolina.

Dr. Geo. C. Brown.—Alcoholic specimens from Mount Holly, New Jersey.

Archibald Campbell.—Collections of animals and plants, made by Dr. C. B. Kennerly, assisted by George Gibbs, esq., and of minerals and fossils made by George Gibbs, in connexion with the Northwest boundary survey, on and near Puget's Sound.

A. Cassidy.—Birds, mammals, and alcoholic specimens from San Diego, Cal.

T. Apoleon Cheney.—Skull and other remains from an Indian mound in Cattaraugus county, N. Y.

E. D. Cope.—Specimens of *Heloecetes feriarum* from New Jersey.

Captain J. M. Don.—Two specimens of the *Pharomacrus* or quesal from Central America.

C. Drexler.—Collections of vertebrata from Fort Bridger. Living *Spermophilus townsendii* and *Cynomys gunnisonii.*

Dr. A. J. Foard, U. S. A.—Skins of *Cyrtonyx massena, Spermophilus grammurus,* and *Thomomys umbrinus* from Texas.

Dr. W. Gesner.—Reptiles and mammals from Western Georgia.

Th. Gill.—Fishes and crustaceans from the West Indies.

Jas. M. Gilliss, jr.—Alcoholic specimens from Florida.

T. Glover.—Living turtles from Florida.

Donald Gunn.—Skins of mammals, birds and alcoholic specimens from North Red river.

Dr. S. E. Hale.—Skulls of mammals from northern New York.

C. T. Hartt.—Fossils from Nova Scotia.

Rufus Haymond, M. D.—Mammals and reptiles from Indiana.

S. Hayes.—*Heloderma horridum* from Gila river.

Dr. Hunter.—Reptiles of North Carolina.

Lieutenant J. C. Ives, U. S. A.—Collection of animals, plants, minerals and fossils from southern California and the Colorado river, and eastward. The animals collected chiefly by H. B. Möllhausen, the remaining objects by Dr. J. S. Newberry.

Dr. Kellogg.—Fruit of the "Mara" of California.

Thos. Kite.—Casts of sculptured foot marks from near Barnesville, Ohio.

Prof. Jos. Le Conte.—Skins of birds of Georgia.

Major J. Le Conte.—*Hyla, Scapheopus, and Rana capito* from Georgia.

Dr. Lummas.—Jar of reptiles and fishes from Kentucky.

Dr. J. C. M'Kee, U. S. A.—Mammals and birds of New Mexico.

J. Mac Minn.—Fossil bones of *Cervus* and *Erethizon* from Pennsylvania.

W. M. M'Lain.—Collection of eggs of North American birds.

Mrs. M'Peak.—Pectoral spine of siluroid fish.

W. M. Magraw.—Five boxes collections vertebrata of Utah, made by C. Drexler, in connexion with South Pass wagon-road expedition.

Judge Merrick.—Scorpion from Nelson county, Ky.

Dr. Geo. F. Moore.—Reptiles from North Carolina.

Lieut. N. Michler, U. S. A.—Collection of animals, plants, &c.,

from the Isthmus of Darien (Atrato expedition,) made by Arthur Schott, assisted by Wm. S. and Charles Wood.

Museum d'Histoire Naturelle, Paris.—Collection of 81 species serpents, types of erpetologie generale.

Alfred Newton.—Pair of stellers ducks, and *Xema minuta.*

Dr. Ed. Palmer.—Fossils from Kansas; skin of wild cat.

J. D. Parker.—Horns of moose, deer, skull of bear, &c., from Maine.

James P. Postell.—Reptiles, mammals, and invertebrates from Georgia.

Patent Office.—Government collections in natural history in Patent Office, consisting chiefly of those gathered by the United States exploring expedition under Captain Wilkes in 1838—1842; by Captain Howard Stansbury in the exploration of the valley of Great Salt Lake; by Captain Sitgreaves in the exploration of the Zuñi and Colorado; by Commodore Perry in his Japan expedition; by Lieut. Herndon on the Amazon, &c. (See page 52.)

Wm. H. Pease.—Fishes, crustaceans, lavas, &c., from Sandwich Islands.

A. Pitman.—Manganese ore from Virginia.

J. P. Postell.—Keg of alcoholic specimens from Georgia.

C. Raymond.—Collections of birds and of alcoholic specimens made in Peru during the astronomical expedition of Lieut. Gilliss.

Dr. Ravenel.—Two bottles of insects from South Carolina.

George M. Roberts.—Box of minerals.

Rev. Joseph Rowell.—Alcoholic specimens from the Isthmus of Panama.

P. L. Sclater.—Skins of Mexican birds.

A. Sharpless.—Collection of birds' eggs from Pennsylvania.

Dr. J. B. Smith, U. S. A., and *Major H. Wayne, U. S. A.*—Skeleton of a camel from Texas.

Dr. J. B. Smith.—*Geomys bursarius* from Kansas.

Judge Steele.—Skin of albino deer; alcoholic collections from the coast of Florida.

J. J. Steenstrup.—Annulata and radiata from Greenland and the West Indies.

F. D. Steuart.—*Heterodon, Jaculus labradorius*, and mink from near Washington.

W. Stimpson.—Fresh *Lophius*, with fishes and invertebrates in alcohol from Massachusetts.

Capt. C. P. Stone.—Shells, fossils, fishes, &c., from the Gulf of California.

Dr. George Suckley.—Jar of serpents from East Indies.

A. S. Taylor.—Marine animals from Monterey, Cal.

Miss Helen Teunison.—Specimens of reptiles and fishes in alcohol, from Mississippi.

Major G. H. Thomas, U. S. A.—Skins of animals and alcoholic specimens, Fort Mason, Texas.

Lieut. W. P. Trowbridge.—Starfish and tail of ray from the sea of Marmora.

Mr. Tufts.—Living marine animals from Massachusetts, for the aquarium.

Major Twiss.—Living grizzly bear from near Fort Laramie.

Union Lead Mines, N. C.—Massive lead ore.

Unknown.—Jar of fishes from Florida.

Unknown.—Box of copper ores from the Perseverance mines, near San Diego, Cal.

J. P. Verreaux.—Skins of Mexican birds.

Dr. Vollum, U. S. A.—Fishes and other animals, and specimens of the "rock oyster," from the coast of Oregon,

Lieut. G. K. Warren, U. S. A.—21 boxes collections of animals, plants, minerals, and fossils, from the valley of the Platte, gathered chiefly by Dr. Hayden.

James Wayne.—Mammals, and skins of fishes of Oregon.

Dr. Weinland.—Invertebrates from Hayti.

John R. Willis.—Collection of birds and their eggs from Nova Scotia.

W. S. Wood.—Alcoholic collections from New Jersey.

G. Wurdemann.—Skins and eggs of birds, and shells and specimens in alcohol from Florida.

John Xantus.—Very large collections of the animals and plants found in the vicinity of Fort Tejon, California.

LIST OF METEOROLOGICAL STATIONS AND OBSERVERS

FOR THE YEAR 1858.

BRITISH AMERICA.

Name of observer.	Station.	N. lat.	W. long	Height.
		° ′	° ′	*Feet.*
Baker, J. C	Stanbridge, Canada East	45 08	73 00	
Craigie, Dr. W	Hamilton, Canada West	43 15	79 57	
Delany, Edward M. J. } Delany, jr., John }	Colonial Building, St. John's, Newfoundland.	47 35	52 38	105
Gunn, Donald	Red River Settlement, Hudson's Bay Territory.	50 06	97 00	853
Hall, Dr. Archibald	Montreal, Canada East	45 30	73 36	57
Hartt, C. F	Horton, Nova Scotia	45 06	64 25	95
Hensley, Rev. J. M	King's College, Windsor, Nova Scotia.	44 59	64 07	200
Magnetic Observatory	Toronto, Canada West	43 39	79 21	108
Smallwood, Dr. Charles	St. Martin, Isle Jesus, Canada East.	45 32	73 36	118

MAINE.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
			° ′	° ′	*Feet.*
Dana, W. D	Perry	Washington	45 00	67 06	100
Gardiner, R. H.	Gardiner	Kennebec	44 11	69 46	90
Gilman, Stephen	East Exeter	Penobscot	45 00	69 00	
Guptill, G. W	Cornishville	York	43 40	70 44	800
Parker, J. D	Steuben	Washington	44 44	67 58	50
West, Silas	Cornish	York	43 40	70 44	784
Willis, Henry	Portland	Cumberland	43 39	70 15	87
Wilbur, Benj. F {	Monson	Piscataquis	43 11	69 35	1,100
	Dexter	Penobscot	44 55	69 32	700

NEW HAMPSHIRE.

Bixby, A. H.	Francestown	Hillsborough	42 59	71 45	
Brown, Branch	Stratford	Coos	44 08	71 34	1,000
Colby, E. P	Concord	Merrimack	43 12	71 29	378
Freeman, F. N	Claremont	Sullivan	43 29	72 22	535
Hanscam, R. F	North Barnstead	Belknap	43 38	71 27	
Odell, Fletcher	Shelburn	Coos	44 23	71 06	700
Purmort, Nath	West Enfield	Grafton	43 30	72 00	
Sawyer, Henry E	Concord	Merrimack	43 12	71 20	400

VERMONT.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
			° ′	° ′	Feet.
Bliss, L. W	West Fairlee	Orange	43 55	72 15	
Buckland, David	Brandon	Rutland	43 45	73 00	
Fairbanks, Franklin	St. Johnsbury	Caledonia	44 25	72 00	540
Marsh, Charles	Woodstock	Windsor	43 36	72 35	740
Jackman, Prof. A	Norwich	Windsor	43 42	72 20	
Paddock, James A	Craftsbury	Orleans	44 40	72 30	1,100
Parker, Joseph	Rupert	Bennington	43 15	73 11	750
Petty, McK	Burlington	Chittenden	44 29	73 11	346

MASSACHUSETTS.

Bacon, William	Richmond	Berkshire	42 23	73 20	1,190
Bond, Prof. W. C	Cambridge	Middlesex	42 22	71 07	71
Davis, Rev. Emerson	Westfield	Hampden	42 06	72 48	
Ellis, D. H	Canton	Norfolk	42 12	71 08	90
Fallon, John	Lawrence	Essex	42 42	71 11	35
Felt, Charles W	Bridgewater	Plymouth	42 00	71 00	150
Lyons, Curtis J.; Berger, M. L.	Williamstown	Berkshire	42 43	73 13	720
Mack, A. W.	Danvers	Essex	42 35	71 03	
Metcalf, Jno. G., M. D.	Mendon	Worcester	42 06	72 33	
Mitchell, Hon. Wm	Nantucket	Nantucket	41 16	70 06	30
Perkins, Dr. H. C	Newburyport	Essex	42 47	70 52	46
Rice, Henry	North Attleboro'	Bristol	41 59	71 22	175
Rodman, Samuel	New Bedford	Bristol	41 39	70 56	90
Sargent, John S.; Blake, George E.; Prentiss, Henry C.	Worcester	Worcester	42 16	71 48	536
Snell, Prof. E. S	Amherst	Hampshire	42 22	72 34	267
Whitcomb, L. F	Florida	Berkshire	42 42	73 10	2,500

RHODE ISLAND.

Caswell, Prof. A	Providence	Providence	41 49	71 25	120

CONNECTICUT.

Edwards, Rev. T., D.D.	New London	New London	41 21	72 12	90
Harrison, Benj F	Wallingford	New Haven	41 26	72 50	133
Hunt, D	Pomfret	Windham	41 52	72 23	596
Johnston, Prof. John	Middleton	Middlesex	41 33	72 39	175
Rankin, James	Saybrook	Middlesex	41 18	72 20	10
Scholfield, N.	Norwich	New London	41 32	72 03	50
Yeomans, William H	Columbia	Tolland	41 42	72 16	

NEW YORK.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
			° ′	° ′	*Feet.*
Alba, Dr. E. M	Angelica	Alleghany	42 15	78 01	1,500
Arden, Thomas B	Beverly	Putnam	41 22	72 12	180
Bowman, John	Baldwinsville	Onondaga	43 04	76 41	
Byram, Ephraim N	Sag Harbor	Suffolk	41 00	72 20	40
Chickering, J. W	Ovid	Seneca	42 41	76 52	800
Dayton, E. A	Madrid	St. Lawrence	44 43	75 33	280
Denning, Wiliam H	Fishkill Landing	Dutchess	41 34	74 18	42
Dewey, Prof. Chester, Ira C. Clark, Isaac C. Seely	Rochester	Monroe	43 08	77 51	516
Guest, W. E	Ogdensburg	St. Lawrence	44 43	75 26	
Holmes, E. S	Wilson	Niagara	43 20	78 56	250
House, J. Carroll	Lowville	Lewis	43 46	75 38	
House, John C	Waterford	Saratoga	42 47	73 39	
Howell, R	Nichols	Tioga	42 00	76 32	
Ingalls, S. Marshall	Pompey	Onondaga	42 56	76 05	1,745
Ives, William	Buffalo	Erie	42 50	78 56	600
Johnson, E. W	Canton	St. Lawrence	44 38	75 15	304
Julien, Alexis A	Schenectady	Schenectady	42 49	73 55	300
Landon, Anna S	Eden	Erie	42 30	79 07	700
Lefferts, John, Covert, A. B	Farmer	Seneca	42 40	76 50	1,000?
Magee, Irving	Spencertown	Columbia	42 19	73 41	800
Malcom, Wm. S	Oswego	Oswego	43 28	77 34	232
Morris, Prof. O. W	New York	New York	40 43	74 05	159
Paine, H. M., M. D	Clinton	Oneida	43 00	75 20	500
	Fordham	Westchester	40 54	74 03	147
Reid, Peter	Lake	Washington	43 15	73 33	
Riker, Walter H	Saratoga	Saratoga	43 06	74 00	960
Sheerar, H. M	Wellsville	Alleghany	42 07	78 06	1,480
Sias, Prof. Solomon	Fort Edward	Washington	43 13	73 42	
Spooner, Stillman	Wampsville	Madison	43 04	75 50	500
Titus, Henry Wm	Bellport	Suffolk	40 44	72 54	
Van Kleek, Rev. R. D	Flatbush	Kings	40 37	74 01	54
White, Aaron	Cazenovia	Madison	42 55	75 46	1,260
Yale, Walter D	Houseville	Lewis	43 40	75 32	
Young, Jude M	West Day	Saratoga	--------	--------	1,200
Zaepffel, Joseph	West Morrisania	Westchester	40 53	74 01	150

NEW JERSEY.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
Cooke, Robert L	Bloomfield	Essex	40 49	74 11	120
Schmidt, Dr. E. R	Burlington	Burlington	40 00	75 12	26
Sergeant, John T	Sergeantsville	Hunterdon	40 29	75 03	
Simpson, B. F, Willis, O. R	Freehold	Monmouth	40 15	74 21	
Whitehead, W. A	Newark	Essex	40 45	74 10	35

PENNSYLVANIA.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
Alsop, Samuel	Westchester	Chester	39 57	75 34	550
Baird, John H	Tarentum	Alleghany	40 37	79 19	950
Barrett, James	Linden	Lycoming	41 10	77 11	

PENNSYLVANIA—Continued.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
			° ′	° ′	*Feet.*
Brown, Samuel	Bedford	Bedford	40 01	78 30	
Brugger, Samuel	Fleming	Centre	40 55	77 53	780
Burrell, J. T.	Bellefonte	Centre	40 50	77 49	
Coffin, Selden J.	Easton	Northampton	40 43	75 16	320
Comly, John	Byberry	Philadelphia	40 06	74 58	
Darlington, Fenelon	Pocopson	Chester	39 54	75 37	218
Edwards, Joseph; Smedley, John H.	Chromedale	Delaware	39 55	75 25	196
Eggert, John	Berwick	Columbia	41 05	76 15	588
Friel, P.	Shamokin	Northumberland	40 45	76 31	920
Hance, Ebenezer	Morrisville	Bucks	40 12	74 53	30
Heisely, Dr. John	Harrisburg	Dauphin	40 16	76 50	
Heyser, William, jr.	Chambersburg	Franklin	39 58	77 45	
Hickok, W. O.	Harrisburg	Dauphin	40 16	76 55	320
Hildebrand, Wm. B.; Peelor, David	Indiana	Indiana	41 15	79 02	1,321
Hoffer, Mary E.	Mount Joy	Lancaster	40 08	76 70	
Jacobs, Rev. M.	Gettysburg	Adams	39 51	77 15	
James, Prof. Charles S.	Lewisburg	Union	40 58	76 58	
Kirkpatrick, Prof. J. A.	Philadelphia	Philadelphia	39 57	75 11	60
Kohler, Edward	North Whitehall	Lehigh	40 40	75 26	250
Martin, William; Speer, Dr. Alex. M.	Pittsburg	Alleghany	40 30	80 00	
Meybert, Dr. A. P.	Scranton	Luzerne	41 25	75 43	1,100
Mowry, George	Somerset	Somerset	40 02	79 02	2,180
Peale, Dr. J. Burd; Hahn, Charles	Reading	Berks	40 19	75 56	263
Ralston, Rev. J. Grier	Norristown	Montgomery	40 08	75 19	153
Smith, Prof. Wm	Canonsburg	Washington	40 25	80 07	936
Stewart, Thos. H.	Murrysville	Westmoreland	40 28	79 35	960
Swift, Dr. Paul	West Haverford	Delaware	40 00	75 21	400
Thickstun, T. F.	Meadville	Crawford	41 39	80 11	1,088
Wilson, Prof. W. C.	Carlisle	Cumberland	40 12	77 11	500
Wilson, W. W.	Pittsburg	Alleghany	40 32	80 02	1,026

DELAWARE.

Martin, R. A	Milford	Kent	39 55	75 27	25
Porter, Mrs. E. D.	Newark	New Castle	39 38	75 47	120

MARYLAND.

Baer, Miss H. M.	Shellman Hills	Carroll	39 23	76 57	700
Bell, Jacob E	Leitersburg	Washington	39 35	77 30	
Clark, Prof. A. W	Chestertown	Kent	39 14	76 02	
Cofrau, L. R	Oakland	Alleghany	39 40	79 00	
Goodman, Wm. R	Annapolis	Anne Arundel	38 58	76 29	20
Hanshew, Henry E	Frederick	Frederick	39 24	77 26	
Lowndes, Benj. O	Bladensburg	Prince George	38 57	76 58	70
Mayer, Prof. Alfred M.	Baltimore	Baltimore	39 18	76 37	
McWilliams, Dr. Alexander.	Leonardtown	St. Mary's	38 17	76 43	

DISTRICT OF COLUMBIA.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
			° ′	° ′	Feet.
Smithsonian Institution.	Washington	Washington	38 53	77 01	60

VIRGINIA.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
Astrop, Col. R. F.	Crichton's Store	Brunswick	36 40	77 46	500
Boyers, Wm. R.	Buffalo	Putnam	38 38	81 57	
	Point Pleasant	Mason	38 50	82 31	
Couch, Samuel	Buffalo	Putnam	38 38	81 57	
Dickinson, George C	Rougemont	Albemarle	38 05	78 21	450
Fraser, James	Mustapha	Wood	39 20	81 41	
Hallowell, Benjamin	Alexandria	Alexandria	38 48	77 01	56
Hoff, Josiah W	Wirt C. H	Wirt	39 05	81 26	
Hotchkiss, Jed	Mossy Creek	Augusta	38 20	79 05	
Johnson, Enoch D.	Sisterville	Tyler	39 34	80 56	540
Kendall, James E.	Kanawha C. H.	Kanawha	38 20	81 21	1,720
Mackee, Rev. C. B.	Anna	Fairfax	38 56	77 04	380
Marvin, John W.	Winchester	Frederick	39 15	78 10	
Patton, Thomas, M. D. / Stalnaker, J. W., M. D.	Lewisburg	Greenbrier	38 00	80 00	2,000
Purdie, John R	Smithfield	Isle of Wight	36 50	76 41	100
Reynolds, W. C.	Kanawha Salines.	Kanawha	38 30	81 30	
Ruffin, Julian C	Ruthven	Prince George	37 21	77 33	
Sanders, B. D.	Holliday's Cove	Hancock			
Slaven, James	Meadow Dale	Highland	38 23	79 35	
Spence, Edward E.	Montross.	Westmoreland	38 07	76 46	200
Upshaw, George W	Rose Hill	Essex	38 00	76 57	250
Van Doren, Abram	Hartwood	Stafford	38 15	77 34	350
Webster, Prof. N. B.	Portsmouth	Norfolk	36 50	76 19	34
Wells, J. Carson	Salem	Roanoke	39 20	80 01	1,300

NORTH CAROLINA.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
Drysdale, Robt. H.	Marlboro'	Pitt			
Johnson, Dr. W. M.	Warrenton	Warren	36 30	78 15	
Kerr, Prof. W. C.	Davidson College	Mecklenburgh	35 30	80 54	850
McDowell, Rev. A.	Murfreesboro'	Hertford	36 30	77 06	
McDowell, W. W.	Asheville	Buncombe	35 37	82 29	2,250
Moore, Geo. F., M. D.	Gaston	Northampton	36 32	77 45	
Morelle, Rev. Daniel	Goldsboro'	Wayne	35 20	77 51	
Phillips, Rev. Jas., D. D	Chapel Hill	Orange	35 54	79 17	

SOUTH CAROLINA.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
Cornish, Rev. John H.	Aiken	Barnwell	33 32	81 34	565
Glennie, Rev. Alex'r.	Waccaman	All Saints	33 40	79 17	20
Johnson, Joseph, M. D / Dawson, J. L, M. D	Charleston	Charleston	32 46	80 00	30
Ravenel, Thomas P.	Black Oak	Charleston	33 00	80 00	50
Tew, Capt. C. C.	Columbia	Richland	34 00	81 07	295

GEORGIA.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
			° ′	° ′	Feet.
Anderson, Jas., M. D.	The Rock	Upson	32 52	84 23	833
Arnold, Mrs. J. T.	Zebulon	Pike	33 07	84 26	
Doughty, Wm. H.	Augusta	Richmond	33 27	81 33	152
Easter, Prof. John D.	Athens	Clarke	33 58	83 80	850
Gibson, R. T.	Whitemarsh Is'd.	Savannah	32 04	81 05	18
Grant, Dr. W. T.	Thomson	Columbia			
Glover, Eli S.	Hillsboro'	Jasper	33 13	83 45	566
Pendleton, E. M., M. D.	Sparta	Hancock	33 17	83 09	550
Posey, John F., M.D.	Savannah	Chatham	32 05	81 07	42

FLORIDA.

Bailey, James B.	Gainesville	Alachua	29 35	82 26	184
Baldwin, A. S., M. D.	Jacksonville	Duval	30 30	82 00	13
Batchelder, F. L.	Hibernia	Duval	30 15	81 30	15
Bean, James B.	Micanopy	Alachua	29 35	82 32	78
Dennis, Wm. C.	Salt Ponds	Key West	24 33	81 48	
Hester, Lt. J. W., U.S.N.	Pensacola	Escambia	30 20	87 16	12
Ives, Edward R.	Alligator	Columbia	30 12	82 37	174
Mauran, P. B., M. D.	St. Augustine	St. John's	29 48	81 35	8
Steele, Judge Aug.	Cedar Keys	Levy	29 07	83 02	12
Whitner, Benj. F.	Belair	Leon	30 24	84 20	70

ALABAMA.

Alison, H. L., M. D.	Carlowville	Dallas	32 10	87 15	300
Darby, Prof. John	Auburn	Macon	32 37	85 34	821
Jennings, Dr. S. K.	Selma	Dallas	32 25	86 51	200
Tutwiler, Henry	Greene Springs	Greene	32 50	87 46	500
Walker, Robert B.	Greensboro'	Greene	32 40	87 34	350

MISSISSIPPI.

Luff, James S.	Columbus	Lowndes	33 30	88 29	227
McCary, Robert	Natchez	Adams	31 34	91 25	264
Robinson, Rev. E. S.	Paulding	Jasper	32 20	82 20	

LOUISIANA.

Kilpatrick, A. R., M. D.	Trinity	Chatahoula	31 30	91 46	108
Merrill, Edward, M. D.	Trinity	Chatahoula	31 37	91 47	68

TEXAS.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
			° ′	° ′	Feet.
Brightman, John C	Goliad	Goliad	28 30	97 15	50
Friedrich, Otto	New Braumfels	Comal	29 41	98 15	
Gantt, Dr. Wm. H	Union Hill	Washington	30 11	96 31	540
Gibbs, T	Huntsville	Walker			
Palm, Swante	Austin	Travis	30 15	97 47	
Rucker, B. H	Washington	Washington	30 26	96 15	
Van Nostrand, J	Austin	Travis	30 20	97 46	650
Yoakum, F. L	Larissa	Cherokee	31 45	95 20	

TENNESSEE.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
Stewart, Prof. Wm. M	Clarkesville	Montgomery	36 28	87 13	481
Tuck, W. J., M. D	Memphis	Shelby	35 08	90 00	262

KENTUCKY.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
Beatty, O	Danville	Boyle	37 40	84 30	950
Grinnell, J	Nolin	Hardin	37 10	85 35	
Lunemann, John H	Bardstown	Nelson	37 52	85 18	
Ray, L. G., M. D	Paris	Bourbon	38 16	84 07	810
Savage, Rev. Geo. S	Millersburg	Bourbon	38 20	84 20	804
Williams, S. R	Louisville	Jefferson	38 03	85 30	452
Young, Mrs. Lawrence.	Springdale	Jefferson	38 07	85 34	570

OHIO.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
Abell, B. F	Welchfield	Geauga	41 23	81 12	1,115
Ammen, J	Ripley	Brown	38 47	83 31	
Anthony, Newton	Mount Union	Stark	41 20	81 01	
Atkins, Rev. L. S	Madison	Lake	41 49	81 10	
Benner, J. F	New Lisbon	Columbiana	40 45	80 46	961
Bennett, Sarah E	Collingwood	Lucas	41 49	83 34	
Clarke, Wm. P	Medina	Medina	41 07	81 47	1,206
Colburn, Edward	Cleveland	Cuyahoga			
Gilmor, Moses	Jackson	Jackson	39 10	82 32	666
Groneweg, Lewis	Dayton	Montgomery	39 30	84 10	720
Harper, Geo. W	Cincinnati	Hamilton	39 06	84 27	150
Haywood, Prof. John	Westerville	Franklin	40 04	83 03	
Herrick, James D	Jefferson	Ashtabula	42 00	81 00	
Hollenbeck, F	Perrysburg	Wood	41 39	83 40	
Hurtt, Francis W	Cincinnati	Hamilton	39 06	84 34	
Hyde, Gustavus A	Cleveland	Cuyahoga	41 30	81 40	665
Ingram, John, M. D	Savannah	Ashland	41 12	82 31	
Jaeger, H. Wm	Lancaster	Fairfield	39 41	82 37	1,000
King, Mrs. Ardelia C	Unionville	Lake	41 52	81 00	650
Luther, S. M	Hiram	Portage	41 20	81 15	675
Mathews, Joseph McD	Hillsborough	Highland	39 13	83 30	1,000
Peck, W. R., M. D	Bowling Green	Wood	41 27	83 45	700
Poe, James H	Portsmouth	Scioto	38 50	82 49	468
Rogers, A. P	Gallipolis	Gallia	39 00	82 01	520

OHIO—Continued.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
			° ′	° ′	*Feet.*
Sanford, Prof. S. N.	Granville	Licking	40 03	82 34	995
Sanford, Smith	Edinburg	Portage	41 20	81 00	520
Shaw, Joseph	Bellefontaine	Logan	40 21	83 40	1,031
Shields, Rev. Robert; Smith, John C	Bellecentre	Logan	40 28	83 45	1,170
Treat, Samuel W	Windham	Portage	41 10	81 05	
Ward, Rev. L. F.	Medina	Medina	41 07	81 47	1,206
	Avon	Lorain	41 27	82 04	800
Williams, Prof. M. G.	Urbana	Champaign	40 06	83 43	1,015
Wilson, Prof. J. H.	College Hill	Hamilton	39 19	84 26	800
Young, Prof. Chas. A.; Childs, E. W	Hudson	Summit	41 15	81 24	1,137

MICHIGAN.

Allen, James, jr.	Port Huron	St. Clair	42 53	82 24	606
Blaker, Dr. G. H., jr.	Marquette	Marquette	46 32	87 41	630
Campbell, Wm. M., M.D.	Battle Creek	Calhoun	42 20	85 10	750
Crosby, J. B.	New Buffalo	Berrien	41 45	86 46	661
Currier, Alfred O	Grand Rapids	Kent	43 00	86 00	752
Pitcher, Dr. Zena.; Horton, L. S	Detroit	Wayne	42 24	82 58	597
Streng, L. H.	Grand Rapids	Kent	43 00	86 00	625
Walker, Mrs. Octavia C.	Cooper	Kalamazoo	42 40	85 31	
Whelpley, Miss H. I	Monroe	Monroe	41 56	83 22	590

INDIANA.

Barnes, Charles	New Albany	Floyd	38 17	85 45	
Chappellsmith, John	New Harmony	Posey	38 08	87 50	320
Crisp, John F.	Evansville	Vanderburgh	38 08	87 29	390
Lasselle, Charles B.	Logansport	Cass	40 45	86 13	600
Moore, Joseph	Richmond	Wayne	39 47	84 47	800
Smith, Hamilton, jr	Cannelton	Perry	37 58	86 40	450
Vaguier, Prof. Thos.	Notre Dame	St. Joseph	41 45	86 10	
Woodard, C. S	Michigan City	La Porte	41 41	86 53	622

ILLINOIS.

Babcock, Andrew J	Aurora	Kane	41 40	88 15	600
Babcock, E.	Riley	McHenry	42 08	88 33	650
Baker, Frank	South Pass	Union	37 28	89 14	1,050
Bowman, Dr. E. H.	Edgington	Rock Island	41 25	90 46	
Brendel, Fred'k, M. D.	Peoria	Peoria	40 36	89 30	
Cantril, Joshua E.	Waynesville	De Witt	40 16	89 07	
Capen, E	Batavia	Kane	41 52	88 20	636
Collier, Prof. Geo. H.	Wheaton	Du Page	41 49	88 06	682
Dudley, Timothy	Jacksonville	Morgan	39 30	90 06	
Eldredge, William V.	Brighton	Macoupin	39 00	90 13	

ILLINOIS—Continued.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
			° ′	° ′	Feet.
Grant, John	Manchester	Scott	39 33	90 34	683
Hall, Joel	Athens	Menard	39 52	89 56	
Harris, J. O., M. D.	Ottawa	La Salle	41 20	88 47	500
James, John, M. D.	Upper Alton	Madison	39 00	89 36	
Meacham, H. G.	Evanston	Cook	42 00	10 50	
Mead, S. B., M. D.	Augusta	Hancock	40 12	89 45	
Mead, Thompson	Batavia	Kane	41 52	88 20	636
Newcomb, John B.	Elgin	Kane	42 00	88 15	600
Riblet, J. H.	Pekin	Tazewell	40 36	89 45	
Rogers, O. P.	Marengo	McHenry	42 14	88 38	650
Smith, Isaac H.	Fremont Centre	Lake	42 18	88 06	736
Swain, John, M. D.	West Urbana	Champaign	40 09	88 17	550
Titcomb, John S.	Hillsboro'	Montgomery	39 12	89 26	
Titze, Henry A.	West Salem	Edwards	38 30	88 00	
Tolman, James W.	Winnebago Depot	Winnebago	42 17	89 11	800
Whitaker, Benjamin	Warsaw	Hancock	40 20	91 31	

MISSOURI.

Englemann, George. } Wislizenus, A., M. D. }	St. Louis	St. Louis	38 37	90 16	461

IOWA.

Beal, Dexter	Franklin	Buchanan	42 45		
Beeman, Carlisle D.	Rossville	Allamakee	43 10	91 21	1,400
Fory, John C.	Bellevue	Jackson	42 15	90 25	
Goss, William K.	Border Plains	Webster	42 36	94 05	
Horr, Asa, M. D.	Dubuque	Dubuque	42 30	90 52	1,258
McConnell, Townsend	Pleasant Plain	Jefferson	41 07	91 54	
McCready, Daniel	Fort Madison	Lee	40 37	91 28	
Odell, Rev. Benj. F.	Pleasant Spring	Delaware			
Parker, Nathan H.	Clinton Davenport	Clinton Scott	41 48	90 15	
Parvin, T. S.	Muscatine	Muscatine	41 26	91 05	586
Reynolds, W.	Iowa City	Johnson	41 39	91 33	
Saville, Dr. J. J.	Sioux City	Woodbury	42 31	96 25	
Shaffer, J. M., M. D.	Fairfield	Jefferson	41 01	91 57	940

WISCONSIN.

Bean, Professor S. A.	Waukesha	Waukesha	42 50	88 11	833
Breed, J. Everett	New London	Waupacca	44 21	88 45	
Blanding, William M.	Falls of St. Croix	Polk	45 30	92 40	660
Durham, W. J.	Racine	Racine	42 49	87 40	
Ellis, Edwin, M. D.	Bay City	La Pointe	46 33	91 00	658
Gridley, Rev. John	Kenosha	Kenosha	42 35	87 50	600
Horsford, William F.	Mount Morris	Waushara	44 06	89 14	

WISCONSIN—Continued.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
			° ′	° ′	*Feet.*
Lapham, Increase A.	Milwaukie	Milwaukie	43 03	87 57	593
Lüps, Jacob	Manitowoc	Manitowoc	44 07	87 37	
Mason, Prof. R. Z.	Appleton	Outagamie	44 10	88 35	800
Nourse, Harvey J.	Bayfield	La Pointe			
Pickard, J. L., M. D.	Platteville	Grant	42 45	91 00	
Pomeroy, F. C.	Milwaukie	Milwaukie	43 04	87 59	658
Porter, Prof. Wm.	Beloit	Rock	42 30	89 04	750
Schue, A., M. D.	Madison	Dane	43 05	89 25	892
Sterling, Prof. J. W.	Madison	Dane	43 05	89 25	892
Struthers, R. H.	Lind	Waupacca	44 20	89 00	
Underwood, Col. D.	Menasha	Winnebago	44 13	88 18	
Winkler, C., M. D.	Milwaukie	Milwaukie	43 04	87 57	593
Willard, J. F.	Janesville	Rock	42 42	89 91	768

MINNESOTA.

Clarke, Thomas	Beaver Bay	Lake	47 12	91 24	675
Garrison, O. E.	Princeton	Benton	45 50	93 45	
Hibbard, A. A.	Burlington	Lake	47 01	92 30	645
Hillier, Spencer L.	Wabashaw	Wabashaw	44 30	92 15	850
McMullen, J. F. } Shortwell, Dan. F. }	Lapham	Pembina	46 10	96 00	850
Riggs, Rev. S. R.	Hazlewood		45 00	95 30	
Van Voorhes, A.	Stillwater	Washington	45 04	92 45	756
Walsh, Stephen	Buchanan		47 33	92 00	

NEBRASKA.

Bowen, Anna M. J.	Elkhorn City	Douglas			
Byers, William N.	Omaha	Douglas	41 15	96 10	
Hamilton, Rev. Wm.	Bellevue	Sarpy	41 08	95 50	
Smith, Charles B.	Brownville	Nemaha	40 30	96 00	

KANSAS.

Berthoud	Leavenworth	Leavenworth	39 19	94 50	800
Brown, G. W.	Lawrence	Douglas	38 58	95 12	800
Fish, Edmund	Council City	Shawnee	38 42	95 50	
Giles, Foy W.	Topeka	Shawnee	39 04	95 40	
Goodnow, Isaac T.	Manhattan	Riley	39 13	96 45	
Himoe, S. O., M. D.	Mapleton	Bourbon	38 04	94 51	
McCarty, H. D.	Leavenworth City	Leavenworth	39 20	94 33	1,342

OREGON.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
			° ′	° ′	*Feet.*
Snyder, James A.	Fort Snyder	Thomson Pass	42 00	--------	8,010

UTAH.

Phelps, Henry E. Phelps, W. W.	Great Salt Lake City.	--------------	40 45	111 26	4,250

MEXICO.

Name of observer.	Station.	Lat.	Long.	Height.
		° ′	° ′	*Feet.*
Laszlo, Charles	Minititlan, Tehuantepec	17 59	94 07	16

CENTRAL AMERICA.

Camedas, Antonio	Guatemala, Guatemala	14 15	90 34	
Dorat, Charles, M. D.	La Union, San Salvador	13 00	88 00	

SOUTH AMERICA.

Fendler, Aug	Colonia Tovar, Venezuela Caracas, Venezuela	10 26	67 20	6,500
Hering, C. J.	Plantation Catharina Sophia, Colony of Surinam, Dutch Guiana	5 48	56 47	

BERMUDA.

Royal Gazette	Centre Signal Station, St. Georges			

Stations from which telegraphic reports of the weather were received at the Smithsonian Institution by the Morse line, during the year 1858.

New York, N. Y.
Philadelphia, Pa.
Pittsburg, Pa.
Baltimore, Md.
Frederick, Md.
Hagerstown, Md.
Cumberland, Md.
Richmond, Va.
Petersburg, Va.
Norfolk, Va.
Lynchburg, Va.
Grafton, Va.
Wheeling, Va.
Parkersburg, Va.
Marietta, Ohio.
Chilicothe, Ohio.
Cincinnati, Ohio.
Bristol, Tenn
Knoxville, Tenn.
Chatanooga, Tenn.
Wilmington, N. C.
Columbia, S. C.
Charleston, S. C.
Augusta, Ga.
Savannah, Ga.
Macon, Ga.
Columbus, Ga.
Montgomery, Ala.
Lower Peach Tree, Ala.
Mobile, Ala.
Gainesville, Miss.
New Orleans, La.

REPORT OF THE EXECUTIVE COMMITTEE.

The Executive Committee respectfully submit to the Board of Regents the following report of the receipts and expenditures of the Smithsonian Institution during the year 1858, with estimates for the year 1859.

Receipts.

The whole amount of Smithson's bequest deposited in the treasury of the United States is $515,169, from which an annual income, at 6 per cent., is derived, of		$30,910 14
Extra fund from unexpended income invested as follows:		
In $75,000 Indiana 5 per cent. bonds, yielding	$3,750 00	
In $53,000 Virginia 6 per cent. bonds, yielding	3,210 00	
In $7,000 Tennessee 6 per cent. bonds, yielding	420 00	
In $500 Georgia 6 per cent. bonds, yielding	30 00	
In $100 Washington 6 per cent. bonds, yielding	6 00	
		7,416 00
		38,326 14
Balance in hands of treasurer January 1, 1858		10,341 30
		48,667 44

Expenditures.

For building, furniture, and fixtures	$1,107 87	
For items common to the different objects of the Institution	9,619 03	
For publications, researches, and lectures	11,956 83	
For library, museum, and gallery of art	9,814 29	
		32,498 02
Balance in the hands of the treasurer January 1, 1859, of which $5,000 belongs to the extra fund		16,169 42

Statement in detail of the expenditures in 1858.

BUILDING, FURNITURE, AND FIXTURES, ETC.

Repairs and incidentals	$566 62	
Furniture and fixtures	497 99	
Magnetic observatory	43 26	
		$1,107 87

GENERAL EXPENSES.

Meetings of Board and Committees	$301 38	
Lighting and heating	712 23	
Postage	442 35	
Transportation and exchanges	1,134 65	
Stationery	413 00	
General printing	192 25	
Apparatus	266 57	
Laboratory	243 60	
Incidentals general	376 17	
Salaries, secretary	3,500 03	
chief clerk	1,400 00	
book-keeper, janitor, watchmen, &c.	509 68	
Extra clerk hire	127 12	
		9,619 03

PUBLICATIONS, RESEARCHES, AND LECTURES.

Smithsonian Contributions to Knowledge	$6,834 02	
Reports on progress	1,053 79	
Other publications	654 24	
Meteorology	2,345 62	
Investigations, computations, and researches	130 00	
Lectures	939 16	
		11,956 83

LIBRARY, MUSEUM, AND GALLERY OF ART.

Cost of books	$3,258 51	
Pay of assistants in library	1,000 00	
Transportation for library	439 70	
Incidentals for library	357 70	
Museum, salary	2,000 00	
Explorations	114 13	
Collections	675 25	
Incidentals for museum, jars, alcohol, &c	1,074 90	
Transportation for museum	368 26	
Assistants and labor, museum	404 64	
Gallery of art	121 20	
		9,814 29
Total expenditure		32,498 02

The estimated income for the year 1858, inclusive of the balance in the hands of the treasurer, was $38,326 14, and the actual income was the same, no change having taken place in the amount received from the interest on the extra fund.

The estimated expenditure was $37,000. The actual expenditure was $32,498. This difference, which is nearly $4,500, has been saved principally on the building, transportation, and the payment of assistants.

The last mentioned item has been somewhat diminished by the payment from the appropriation of Congress for the keeping of the museum of the exploring expeditions which has been transferred from the Patent Office to the Smithsonian Institution. The amount received for the last six months on this account has been about $2,000. This sum is not credited to the Institution, because the money is disbursed by the Secretary of the Interior.

The amount of income above that of the expenditure was $5,828 12. This sum has been saved with the view of carrying out the design mentioned in the last report, namely, that of accumulating a sufficient sum in the treasury to enable the payment of cash for all purposes, and thus to save the extra charge which, in almost all cases, is made when payment is deferred.

The amount in the treasury at the beginning of the present year for carrying on the operations until the time of receiving the next income was $16,169 42. Of this, however, $5,000 belong to the extra fund, which has not yet been invested. According to the statement of the secretary, the Institution, at the beginning of 1859, had no outstanding debts, and hence it appears that the funds are in a good condition.

The committee respectfully submit the following estimate of the receipts and expenditures for the year 1859:

ESTIMATE OF THE RECEIPTS AND EXPENDITURES FOR THE YEAR 1859.

Receipts.

Balance in the hands of the treasurer January 1, 1859...	$16,169 42
Interest on the original fund...........................	30,910 14
Interest on the extra fund...............................	7,416 00
	$54,495 56

Expenditures.

BUILDING, FURNITURE AND FIXTURES.

Repairs and incidentals...............................	$1,500 00	
Furniture and fixtures................................	500 00	
Magnetic observatory..................................	100 00	
		$2,100 00

GENERAL EXPENSES.

Meetings of Board and committees	$150 00	
Lighting and heating	1,000 00	
Postage	500 00	
Transportation and exchange	1,500 00	
Stationery	400 00	
General printing	500 00	
Apparatus	500 00	
Laboratory	500 00	
Incidentals, general	700 00	
Salaries.—Secretary	3,500 00	
Chief clerk	1,400 00	
Book-keeper	200 00	
Janitor	400 00	
Watchman	500 00	
Laborers	500 00	
Extra clerk hire	250 00	
		$12,500 00

PUBLICATIONS, RESEARCHES AND LECTURES.

Smithsonian Contributions	$6,000 00	
Reports	2,000 00	
Other publications	600 00	
Meteorology	3,000 00	
Researches	300 00	
Lectures	1,000 00	
		12,900 00

LIBRARY, MUSEUM AND GALLERY OF ART.

Library.—Cost of books	$3,000 00	
Pay of library assistants	1,200 00	
Transportation for library	500 00	
Incidentals for library	100 00	
Museum.—Salary of assistant secretary	2,000 00	
Explorations	100 00	
Collections	150 00	
Incidentals to museum	700 00	
Transportation	600 00	
Assistants and labor	2,000 00	
Gallery of art	150 00	
		10,500 00
		38,000 00

The committee have examined all the books and accounts of the Institution for the past year, and find them to be correct.

Respectfully submitted.

J. A. PEARCE,
A. D. BACHE,
*Executive Committee.**

* General J. G. Totten, the other member of the executive committee, is now in Europe

JOURNAL OF PROCEEDINGS

OF THE

BOARD OF REGENTS

OF

THE SMITHSONIAN INSTITUTION.

WASHINGTON, *January* 19, 1859.

In accordance with a resolution of the Board of Regents of the Smithsonian Institution, fixing the time of the beginning of their annual meeting on the third Wednesday of January of each year, the Board met this day in the Regents' room.

Present: Hon. S. A. Douglas, Hon. William H. English, Hon. James G. Berret, Professor A. D. Bache, Hon. W. W. Seaton, Treasurer, and the Secretary.

The Secretary stated that letters had been received from Hon. Richard Rush, Hon. Gideon Hawley, and Professor C. C. Felton, stating their inability to attend the present annual session of the Board of Regents.

The Treasurer presented a statement of the receipts and expenditures during the year 1858, and also a general statement of the funds; which were referred to the executive committee.

A quorum not being present, the Board adjourned to meet at the call of the Secretary.

TUESDAY, *February* 15, 1859.

A meeting of the Board of Regents of the Smithsonian Institution, was held this day at 11 a. m., in the Vice President's Room, United States Capitol.

Present: Hon. John C. Breckinridge, Hon. James M. Mason, Hon. James A. Pearce, Hon. S. A. Douglas, Hon. William H. English, Hon. L. J. Gartrell, Hon. J. G. Berret, Professor A. D. Bache, and the Secretary.

Mr. Pearce was called to the chair.

The report of the Executive Committee was presented, read and accepted.

The Secretary announced the re-election by joint resolution of the Senate and House of Representatives of the United States, of Professor Alexander Dallas Bache and Hon. George E. Badger, as Regents of the Smithsonian Institution, for the term of six years.

The Secretary then presented the annual report of the operations of the Institution for 1858, which was accepted.

The report of the Executive Committee, presented by Mr. Pearce, was read and accepted.

The following letter was read to the Board.

BREMEN LEGATION,
Washington, January 25, 1859.

SIR: Agreeably to your verbal request, I have proposed to the president and directors of the North German Lloyd of Bremen, to manifest their interest in the cause of science, by facilitating literary intercourse between the United States and Germany, by means of their steamers plying between Bremen and New York.

It affords me great pleasure now to inform you that, according to a letter of the president of the Lloyd, dated the 5th instant, and just received, the said Bremen steamship company have resolved, henceforth, and until further notice, to forward by their steamers all the packages of books and specimens of natural history which the Smithsonian Institution may be pleased to send to Germany, or which may be sent from Germany to the Smithsonian Institution, *free of charges between New York and Bremenhaven.*

I beg leave to add that Messrs. Gelpcke, Keutgen and Reichelt, 84 Broadway, New York, are the agents of the North German Lloyd at that place, and that the next Bremen steamer sailing for Europe will leave New York on the 19th of February next.

I avail myself of this occasion to offer you renewed assurances of my high consideration.

R. SCHLEIDEN,
Minister Resident of Bremen.

Professor JOSEPH HENRY,
Secretary of the Smithsonian Institution.

On motion of Mr. Mason, the following resolution was adopted by the Board.

Resolved, That the thanks of this board be returned to his excellency, R. Schleiden, minister resident of Bremen, for his intervention with the "North German Lloyd of Bremen" to facilitate and advance the cause of science by transporting, free of charge &c., packages of books, and specimens of natural history, from Germany

to the Smithsonian Institution, and from the Institution to Germany, and the like thanks to the president and directors of the North German Lloyd of Bremen, for their generous liberality in the instance above referred to.

The Secretary stated that thanks were due to several companies for their liberality to Lieutenant Gilliss, who had visited South America in September last, to make observations of the eclipse, under the auspices of the Smithsonian Institution.

On motion of Mr. Mason, the following resolution was adopted:

Resolved, That the thanks of the Board of Regents are hereby given to the British Pacific Steamship Navigation Company; the United States Mail Steamship Company; the Pacific Mail Steamship Company; and the Panama Railroad Company, for their generous aid in the cause of science, by transporting free of charge, with other facilites, extended to Lieutenant Gilliss, U. S. N., in his late expedition to Peru, under the auspices of the Smithsonian Institution, to observe in that country the total solar eclipse of September 7, 1858.

Communications were read from Rev. F. Vinton, of Brooklyn, relative to the Wynn estate, of which he is one of the two executors; from Hon. J. H. Hammond, and J. R. Lambdin, esq., relative to procuring copies of celebrated works of art in Europe.

On motion of Mr. Douglas, the following resolution was adopted:

Resolved, That the sum of two thousand dollars be appropriated, to be expended at the discretion of the executive committee, for procuring castings, or moulds for castings, of the *chef d'oeuvres*, of art in Europe.

A communication from Professor S. F. Baird, asking an increase of salary, was read, and referred to the executive committee.

A communication from Professor S. F. Morse, dated Paris, October 16, 1858, and a letter from Hon. Amos Kendall, were presented to the Board, and both were referred to the special committee, which had made a report in relation to the telegraph at the meeting of May 19, 1858.

The following communication was presented.

13 Ashley Place,
London, January 8, 1859.

My Dear Sir: I sent you from Leeds, in September, a printed copy of the report of the joint committee of the Royal Society and the British Association, on the subject of the continuance of magnetic observations drawn up by Sir John Herschel. You will have been ap-

prised by it of the serious purpose entertained in this country to prosecute the magnetic researches which have already, though quite in their infancy, established so many important laws. The minutes of the last meeting of the council of the British Association, will make you acquainted with our subsequent proceedings.

Our government has postponed the decision of the precise measures to be taken until next year ; and indeed our preparations, both of instruments and observers, could scarcely have been ready earlier, but I think that we may entertain very sanguine hopes of establishing some observatories at least; and I have the more confident expectation of this from the letter of the Prince Consort of December 11, (which you will see in the enclosed minutes,) who is to be our president next year, (at the B. A.,) and who will then be the medium of our communications with government. But still we may derive great support from any evidence which we may be able to adduce that other countries besides our own participate in the scientific interest of these researches, and it is specially in this view that I now write to you.

Our government appears not indisposed to have an observatory at Pekin, and we shall no doubt press strongly to have a second at Vancouver's Island. Toronto is already a third observatory in action in nearly the same latitude, and London a fourth. It is obvious that a chain of stations at moderate distances from each other in the middle latitudes of the one hemisphere would give us a very reasonable prospect of establishing with confidence laws the existence of which we can now only infer. The greatest interval is between London and Pekin, but this I have some reason to hope may be supplied by an observatory at Kazan, under the able direction of Professor Bolzani, and it is impossible under these circumstances not to desire that the observatory which you have so long meditated at Washington, should be brought into corresponding activity.

It is purposed that the instruments for the new British observatories should serve either for eye observations or for a continuous record of the three elements. They will be in great measure on the model of the self-recording instruments at Kew, which have now been at work for a twelvemonth, and which seem indeed to leave little to be desired. But those for the colonial observatories will be somewhat differently arranged, so as to occupy a space not exceeding perhaps twelve feet by six, and to have all their parts so attached to a solid floor that nothing is capable of misplacement. We find at Kew that two persons are sufficient for the manipulations of such an observatory, the preparation of the paper, &c., and the tabulation from the traces by instrumental measurement at hourly intervals.

The instruments for the first either colonial or extra English observatory are in hand, and will be at work we expect in a temporary building in the grounds of the observatory at Kew in July or August next, where, should you incline to come once more to our British Association meeting, which is to be held this year at Aberdeen, under the Prince Consort, or should any friend do so in whose judgment you can confide, there will be a full opportunity for examining them.

I cannot conclude this letter without again adverting to the support which we should derive in our communications with our government in the event of the Smithsonian Institution concurring with us in the importance of prosecuting these inquiries, and being disposed to adopt corresponding proceedings with, of course, such modifications as may suit either their convenience or their views of the subject.

Believe me, my dear sir, sincerely yours,

EDWARD SABINE.

Professor HENRY.

The above communication was referred to the secretary and executive committee.

The Secretary presented a communication from G. J. Durand, of Bordeaux, accompanied by a report on the history, operations, and publications of the Smithsonian Institution, which that gentleman had presented to the Imperial Academy of Bordeaux.

The board then adjourned *sine die*.

GENERAL APPENDIX

TO THE

REPORT FOR 1858.

The object of this Appendix is to illustrate the operations of the Institution by the reports of lectures and extracts from correspondence, as well as to furnish information of a character suited especially to the meteorological observers and other persons interested in the promotion of knowledge.

LECTURES

ON ASTRONOMY.

BY PROFESSOR A. CASWELL, OF BROWN UNIVERSITY.

1. *The figure and magnitude of the earth.*

Every person who ventures to address a public assembly is supposed to have something to present to them which is worthy of their attention, and which they can understand. In the treatment of scientific subjects he must occupy himself mainly in giving information respecting the facts and methods and laws of science.

In appearing before you this evening I may be permitted, I trust, without arrogance on my part or disparagement to you, to say that my object is instruction. Any object lower than this would ill become this place and the character of this noble Institution, which is doing so much to stimulate investigation and develop the scientific resources of our country. I wish to unfold to you the elementary methods by which the astronomer advances step by step in investigation, until he spans the heavens with his measuring rod and weighs the far off planetary bodies as in a balance, and marks the point in the starry concave where the flaming comet will disappear in the depths of ether, and that other point with almost equal precision where it will reappear after the flight of centuries. There are in astronomy refinements of method, both practical and theoretical, which can be appreciated only by rare gifts and profound study. But the elementary methods are quite within the reach of ordinary minds. The law, which it was difficult to discover, may be very easily understood and its results readily traced. It might require a Newton or a La Place to unveil the mechanism of the heavens, but when that is once done every beholder may watch the wonderful evolutions.

To accomplish the purposes I have in view, I must first of all secure your attention. For this I rely more upon the inherent interest and grandeur of the subject than upon any adventitious attractions which I may be able to throw around it.

Astronomy has long claimed the pre-eminence of being the most ancient and the most perfect of the sciences. And yet astronomy, in some of its aspects, is a rapidly progressive and cumulative science.

The number of primary planets known to astronomers has been quadrupled within the last few years. Instead of the five planets known to Ptolemy and Copernicus, and even to Newton, we now have upwards of sixty. Scarcely a month passes that does not add something to the aggregate of our knowledge of the heavens—that does not reveal some new wonder to the telescope, or disclose some new treasure to the far-reaching analysis of the mathematician. Never could it be said with a profounder meaning than now that "the heavens declare the glory of God."

The mechanism of the heavens, in proportion as we comprehend more and more of its vastness and seeming complexity, bears witness to the enduring order and harmony of the universe, and points with unerring certainty to the superintending agency of an intelligent and infinite creator.

In the course of our discussions we shall have occasion not only to state the results of investigation, but to witness the struggles and triumphs of the human mind in working its way to the solution of some of the great problems of science.

We spontaneously pay the tribute of our homage to all great achievements. But in no case is homage more just or more enduring than that which all cultivated minds pay to him who stands as the minister and interpreter of Nature, and makes known to us her laws and her mysteries. Many such adorn the annals of astronomy.

But I must not, in these preliminary remarks, encroach upon the time which belongs to the special subject of the evening, which is —

The figure and magnitude of the earth.

This may be called the great problem of astronomy. Its importance is apparent from this, that the radius of the earth is the *unit of measure*—I may say the measuring rod—which we are compelled to use in determining the dimensions of the solar system. Whatever error obtains in our knowledge of this will be repeated and multiplied in all our estimates of planetary distances. Hence the importance which attaches to this problem, and the great pains which has been taken to solve it with the utmost accuracy.

That the general figure of the earth is *spherical* was an opinion held by many of the ancient astronomers. This was obvious from the manner in which vessels disappear at sea. It was also indicated by the circular shadow of the earth upon the moon in the case of eclipses. In contemplating the extent of countries, and the distance of one country from another, the question of the earth's magnitude would naturally—almost necessarily, be suggested. It would be useless to attempt to trace the successive steps in the progress of this inquiry among the ancients. Aristotle relates that the mathematicians prior to his time had found the circumference of the earth to be 400,000 stadia. But the length of the Greek stadium is unknown, so also is the method by which this result was obtained. The fact mentioned by Aristotle is only of interest as showing that the question had en-

gaged the attention of astronomers at a very early period. Eratosthenes, of Alexandria, appears to have been the first to form a true conception of the method by which the problem could be solved; that is, by the measurement of an arc of the terrestrial meridian. Nearly three centuries (276 years) before the Christian era, by such rude methods as were then in use, he determined the distance from Alexandria to Syene in upper Egypt to be $\frac{1}{83}$ of the whole circumference of the earth. From the measured distance between the two cities he computed the circumference of the earth to be 250,000 stadia. Somewhat later Posidonius, also of the Alexandrine school, resumed the inquiry and gave as the result of his measurements 240,000 stadia. But the uncertainty in the length of the stadium renders these results of little value.

Nearly a thousand years later, (A. D. 814,) when the schools of science had been transferred from Egypt and Greece to the banks of the Euphrates, the caliph *Almamoun*, of Bagdad, directed his astronomers to measure a degree of the meridian on the plains of Mesopotamia, with a view to determine the problem of the earth's magnitude. Their result was so nearly coincident with that given by Ptolemy that suspicion was cast upon the genuineness and fidelity of the measurements.

After this period the inquiry seems hardly to have awakened any attention for seven or eight centuries, when it was taken up by modern European astronomers.

Before adverting to the more recent *geodetic operations*, as they are termed, which have given us the exact figure and magnitude of the earth, I may, perhaps, with advantage point out the general method of executing those *operations* and the manner in which we deduce from them the exact dimensions of the earth.

The geodetic operations to which I refer have for their object the measurement of arcs on the earth's surface and chiefly arcs of the meridian. There are other observations and experiments subsidiary to the solution of this problem, to which I shall merely advert in passing. Thus, for instance, the law of attraction for a spheroid having been established, the vibrations of the pendulum in different latitudes will furnish data from which the *figure*, not the magnitude, of the earth can be determined. Many thousands of pendulum experiments have been made in different parts of the earth with this object in view. There are also certain inequalities in the moon's motion, which are produced by the oblate or flattened figure of the earth. These observed inequalities become in the hands of the mathematical astronomer an accurate measure of that oblateness. The results obtained by La Place and others by this method are received with great confidence by the most eminent astronomers. We shall refer to the results obtained by both these methods, which assign the *figure* only, when we have explained the method of finding both the *figure* and also the *magnitude* by the measurements of arcs of the meridian.

The measurement of a meridian line consists of three distinct processes:

1. The line must be run in true north and south direction.

2. The difference of latitude at its extremities, or what is the same thing, the angle made between the plumb-lines, must be determined.

3. The length of the arc in miles, or parts of miles, must be determined.

By the aid of a few simple diagrams I can readily indicate to you how these results are obtained.

1. To run a true north and south line we have only to direct the telescope of a transit instrument on a theodolite to the north star when it is directly *above* or *below* the pole, and then, the axis being horizontal, sight to some well defined object situated to the north and to another at the south. The line passing through these points and continued by sighting to new objects will be the line required. The time, which occurs twice in every twenty-four hours, when the north star is so situated, is easily known from the Nautical Almanac. This is the readiest method of fixing the line. But if the Nautical Almanac is not on hand, the same result is obtained by so placing the instrument that the time between the upper and lower transits of a circumpolar star passing through the western portion of its revolution shall be the same as that in passing from the lower transit through the eastern portion of its revolution to the upper.

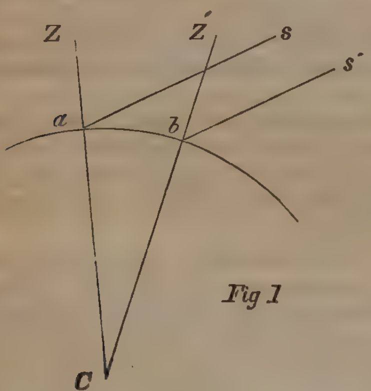


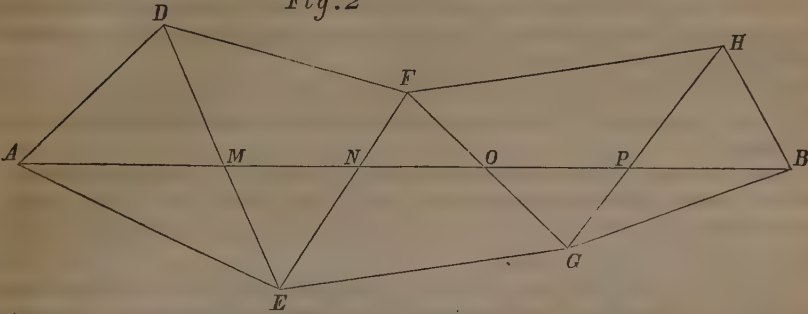
Fig 1

2. To find the angle made between the plumb-line, let *a* and *b*, fig. 1, represent the arc of the meridian; C the centre of the earth; Z and Z′ the zeniths of the two extremities of the line. It is required to find the angle *a* C *b*. This will be the difference in latitude between the two stations. But it is most easily obtained by observing the zenith distance of any star in the vicinity of the zenith as it passes the meridian. Thus Z *a* *s*′ would be the zenith distance of the star at *a*, and Z′ *b* *s*′ the zenith distance at *b*. The difference between these two is the required angle at C. In practice this element is obtained very readily and with great precision.

3. By far the most difficult part of the work is to measure the exact distance between the two points *a* and *b*. This is best done by a system of triangles. Thus, in fig. 2, suppose A and B to be the extremities of the meridian line, and D E F G and H to be prominent points of the country at such elevations as to be visible the one from the other. Commencing the operation at A, a line A D, of several miles in extent, lying along a level plain, if such can be found, is selected and accurately measured. This is called a *base* or *base line*, and the utmost refinement of methods is required for its measurement. The base line having been measured, we place an instrument, adapted to the measurement of horizontal and vertical angles, (usually a large theodolite,) at A, and measure the horizontal angle D A E,

and D A M, and also the elevation, if any, of D and E above A. The instrument is then transported to D, and A D E and E D F are measured, and also the elevations of F and E above D; and thus in succession the instrument is taken to each of the stations and all the

Fig. 2



horizontal and vertical angles are measured. The sides of all the triangles, varying in length from 10 to 40 or 50 miles, may now be very easily computed. Beginning with A D E, and taking them in succession, we have in each case all the angles and one side given to find the other sides. To test the accuracy of the work a second line, as H B, at or near the extremity of the line is measured. This is called the *base of verification.* If any considerable error is found to exist between the measured and computed length of this line the whole work must be gone over again. But before we can expect any close agreement between the computed and measured length of the base of verification the several stations, D E F and G, must be reduced to the level surface, that is, to the surface of the water, if we should suppose the ocean to flow freely over the land. We must reduce each of the stations to the continued ocean surface. Thus, in fig. 3, A may be situated on the beach, E on the summit of a mountain, A G the curve or line of the ocean surface continued. We must, in fact, reduce the point E to G and compute the length of the curved line A G from knowing the length of the straight line A E and the elevation of the point. My object here is not to give any abstract or synopsis of the method of making this reduction, but only to indicate what is required to be done. The process, though somewhat laborious, presents no peculiar difficulty.

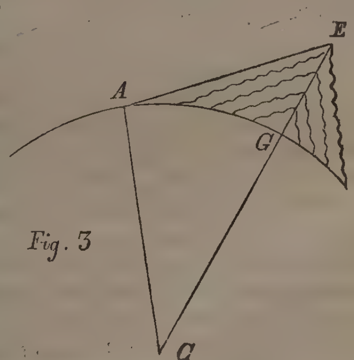


Fig. 3

It now remains to find the distance from A to B along the meridian line reduced to the ocean surface. This we do by resolving in succession the triangles, fig. 2, A D M, M E N, N F O, O G P, and P H B,

in which we shall have known two angles and the included side. Adding the distances A M, M N, N O, O P, and P B, we shall have the entire distance from A to B measured along the continued ocean level. It is thus that science, by her magic touch, levels down the mountains and fills up the valleys, and makes for herself a path which, we may truly say, the vulture's eye hath not seen.

To solve the problem we have in hand, and determine definitely the figure and magnitude of the earth, we must have the results of measurements in different latitudes.

We shall briefly refer to some of the principal measurements which have been executed before we deduce from them the exact dimensions of the earth.

From the early part of the ninth century, when the Arabian astronomers, as before stated, measured an arc of the meridian on the plain of Mesopotamia, this question seems to have been lost sight of for more than six hundred years.

1. In 1528, Fernel, an eminent physician of Paris, revived the problem by measuring the distance from Paris to Amiens, in Picardy, by counting the revolutions of his coach wheels.

2. Nearly a hundred years later, (1617,) Snellens, of Leyden, measured an arc of the meridian, in Holland, between Alkmaer and Bergen-op-Zoom. He was the first to adopt the principle of triangulation.

3. Some few years after the measurement of Snellens, the English astronomer, Norwood, (1635,) measured an arc between London and York. He measured parts of the distance with a chain, other parts by pacing, and where the ground was rough he estimated the distance as well as he could.

The results of these measurements, on account of the imperfection of methods and instruments, are of little or no value. They only indicate the growing interest in the problem.

4. Picard's measurement.

It was not until 1669 that an arc of the meridian was measured with such care and precision as to inspire confidence in the result. This was done by Picard, of the French Academy. *He was the first to apply* the telescope to instruments for the measure of angles. He commenced his operations at Malvoisin, near Paris, and terminated them at Sourdon, near Amiens. For the measurement of terrestrial angles he used a quadrant of 38 inches radius, and for zenith distances a sextant of 10 feet radius.

He found for a degree 60.812 fathoms, a result very near the truth, but it was owing to a fortunate balancing of errors which were subsequently discovered in his work.

5. Up to 1672 no doubt was entertained of the *perfect sphericity* of the earth. During this year a circumstance occurred which had a most important bearing upon this problem. Richer was sent out by the French Academy to Cayenne, in South America, to make observations on the parallax of Mars. He took with him a pendulum, carefully adjusted to beat seconds in Paris. On suspending it at Cayenne, three or four degrees north of the equator, he found that it lost two minutes and twenty-eight seconds per day. He shortened it

to make it beat seconds, and on returning to Paris it was necessary to restore the original length in order again to beat seconds.

Picard had anticipated that a change of temperature would affect the rate, but by no means to so great an extent as two minutes and twenty-eight seconds per day.

The cause of so remarkable a fact of course engaged the attention of astronomers.

Newton and Huygens both assigned the true cause, viz: the diminished force of gravity as a consequence of the centrifugal force and the flattened figure of the earth.

The effect of the centrifugal force may be illustrated by fig. 4. Let E P Q S be a section of the earth made by a meridian circle, P S the axis, E Q the equator, and P C Q an imaginary tube extending from the pole to the centre, and thence to the equator. Let this tube be filled with water and the earth at rest. The two branches would then be of equal length. Now let the earth begin to rotate on the line P S. The water would immediately settle down in P C and rise in C Q.

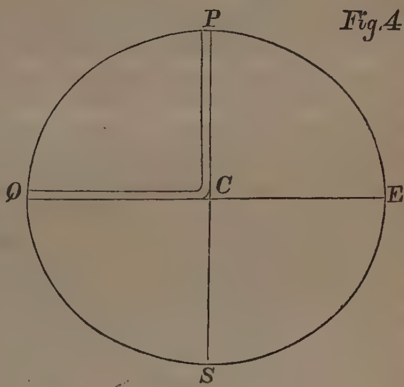


Fig. 4

Newton found the ratio of the two axes to be as 229 : 230. There could be no doubt that the figure was flattened at the pole, the only question was *how much?*

6. To settle a question of so much interest and of so much importance, the French Academy determined on extending the arc of Picard.

In 1683, under the direction of the eminent astronomer royal, Dominic Cassini, the measurement was extended to some distance south of Paris, when the death of the minister, Colbert, suddenly interrupted their labors. They were not resumed till 1701, when the line was extended to Perpignan, on the Mediterranean, 6° south of Paris.

In 1718 James Cassini, son of the former, continued the measurement on the north of Paris to Dunkirk. Thus was this great work completed after thirty years of labor.

The unlooked for result was that a degree at the *northern extremity of the arc was* 145 *fathoms shorter than at the southern.*

The necessary consequence was that the earth was *elongated,* not *flattened,* at the poles, and that the conclusion of the mathematicians was contradicted by the facts.

This opinion, in opposition to those of Newton and Huygens, was maintained by Cassini de Thury and his able coadjutors in the Academy. To confirm so important a result, Cassini measured an arc on a parallel of latitude extending from Strasburg to Brest, and found it 300 toises shorter than it would have been if the earth had been a perfect sphere. In an elaborate work published by him in 1735 he says, as quoted by Delambre, (Hist. Ast. 18th Century, p.

275 :) "Thus all our operations in longitude as well as latitude concur in giving to the earth a figure elongated towards the pole." He adds: "This discovery, so useful to the sciences and to navigation, and so glorious to France, will be due to the Academy."

7. The conflicting results thus obtained, taken in connexion with the importance of the problem, determined the French Academy to send out commissions, one to measure an arc of the meridian near the equator, another in the most northern latitude accessible.

This was in 1735. The commission to the north was committed chiefly to Maupertuis and Clairault, while that to the equator was under the direction of Bouguer and Condamine.

The place selected by Maupertuis and Clairault for the northern line was at the northern extremity of the Gulf of Bothnia, commencing at Tornea, on the gulf, and terminating at a place called Kittis, in latitude 66° 48′ 44″. The work was accomplished amid great difficulties, arising from the severities of the climate. The commission returned after an absence of more than two years. An account of it was published by Clairault in 1743. The length of a degree was found to be 61.195 toises. This result, by subsequent measurement of Swanburg, was found to be slightly erroneous.

The southern commission commenced their operations at Targui in Peru, near the equator, and continued the line to Cotshequi, about 3° south of it. This commission was absent nine years.* A detailed account of the work was given by Bouguer in one volume, 8vo., published 1749. The length of a degree was found to be 60.468 toises.

The results of these measurements dissipated all doubts as to the earth's figure. They showed an unquestionable *lengthening* of the degrees as we go from the equator to the pole, and a consequent flattening at the pole.

8. In the mean time, while these important measurements were in progress in Peru and Lapland, Cassini de Thury, third of the name and grandson of Dominic, in connexion with Lacaille, in 1739, remeasured the entire French arc from Perpignan to Dunkirk, with every possible care which could insure the utmost accuracy in the result. Several errors of former measurements were corrected. The comparison of a degree at the northern and southern extremities of the arc, of some 400 miles in extent left, no room for doubt as to the lengthening of the degrees as we proceed to the north. These three measurements removed all doubts which might have existed as to the figure of the earth. Thus the mathematicians, who deduced the oblateness from principles purely dynamical, had the satisfaction of finding their conclusions confirmed by the most elaborate measurements.

The next object of interest was to determine the exact amount; that is, to determine the exact length of the two axes of the figure; in other words, the equatorial and polar diameters.

9. To determine the exact amount of oblateness, additional measurements in different latitudes and different portions of the earth were necessary.

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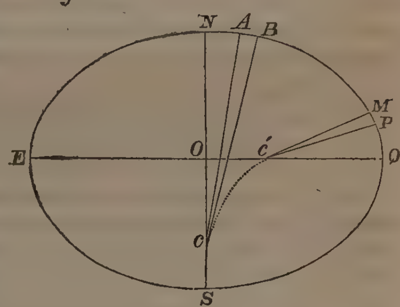
* Left France in May, 1735, returned in 1744.

In 1750 Boscovich and Le Maire measured an arc from Rome to Rimini, a distance of nearly 140 miles.

In 1752 Liesganig measured an arc passing through the observatory of Vienna, and about the same time Beccaria measured another in the plains of Lombardy.

In 1764 Charles Mason and Jeremiah Dixon measured a line of about 100 miles in length along the valley of the Delaware. They were engaged at the time in running the boundary line between the States of Pennsylvania and Maryland, and finding a fine locality for measuring an arc of the meridian, they informed the Royal Society of London of the fact and offered to execute the work if the Society would furnish the requisite instruments. The Society, under the advice of Dr. Maskelyne, the astronomer royal, gladly accepted the offer of Messrs. Mason and Dixon. This line is remarkable as having been actually measured through its whole extent with wooden rods, or rather a wooden frame, sent out for the purpose by the Royal Society. It was made of fir, 20 feet long and 4 feet wide, with adjustments for being leveled by plumb line. This measurement has always been regarded as a very accurate one. The latitude of the middle point of the line is 39° 12′ nearly. This arc is one of the 13 used by Airy in determining the figure of the earth.

Fig 5



10. After the peace 1783 Cassini de Thury addressed a memoir to the Royal Society of London upon the importance to astronomy of determining more accurately than had before been done the difference in longitude between the observatories of Paris and Greenwich. The suggestion was favorably received and commissions were appointed by both governments to carry the project into effect by a trigonometrical survey. General Roy was at the head of the English commission. The French operations were committed to Count Cassini, (the 4th of the name,) Mechain and Legendre.

The English had hitherto taken little part in the prosecution of these important geodetic labors, but the splendid array of instruments and the practical skill which they brought to the work placed them second to no others. The great theodolite, constructed for the purpose by Ramsden, 30 inches in diameter, may almost be said to be the wonder of the age. It certainly marks an important epoch in the history of astronomical instruments. The three angles of every spherical triangle are well known to be greater than two right angles. But this theodolite, in the hands of General Roy, was the first instrument, in the history of science, to show the fact by actual measurement. It is recorded, as a singularly gratifying fact, that in all the primary triangles this *spherical excess* was apparent, and seldom did it exceed 3″ or 4″ of arc.

The work on both sides of the channel was executed with eminen

ability. The computation of the French astronomers, based upon this triangulation, placed the observatory of Paris 9′ 21″ to the east of Greenwich. The computations of Colonel Mudge gave 9′ 19″.4. In the mean time, the difference obtained by Dr. Maskelyne from astronomical observation was 9′ 20″. And nearer than this, it was suggested, the difference probably would never be known; but the *electric telegraph* was not then invented. With this new aid the difference is fixed at 9′ 20″.63. This last is adopted by the English Nautical Almanac.

The triangulation of Great Britain and Ireland now extends from the Scilly islands, in latitude 49° 53′, to the Shetland isles, latitude 60° 50″—a distance of about 750 miles. During the progress of the work, commenced in 1791 and continued to the present time, seven base lines have been measured. The one on Hounslow Heath has been measured three times—once with *deal rods*, once with *glass rods*, and once with a *steel chain* of exquisite workmanship, made by Ramsden. The results were as follows:

Length by deal rods..................	27,405.76	feet.
Length by glass rods.................	27,403.38	"
Length by steel chain................	27,402.38	"

The base on Salisbury plains, of between six and seven miles in length, has been measured twice, first with Ramsden's steel chain and subsequently with General Colby's compensation bars, the latter measure exceeded the former by about one foot. Sir J. Herschel says that the greatest possible error in the Irish line, near Londonderry, of between seven and eight miles in length, is supposed not to exceed two inches.

11. Many other arcs of the meridian have been measured. Three of them deserve to be mentioned, on account of their great extent and the extreme accuracy of the work.

The *first* is the great French arc, commenced in 1791, under order of the National Assembly. The object was to determine a new unit of measure of length, *the metre*, which should be based on an invariable standard in nature. It was determined to make it the $\frac{1}{10000000}$ part of the meridian of the earth from the equator to the pole. This magnificent enterprise was assigned to Delambre and Mechain. Delambre took the northern section, from Paris to Dunkirk. Mechain took the southern, from Paris to Perpignan, and extended the same to Barcelona, in Spain. This arc was subsequently extended, (1806,) by Biot and Arago, to the island of Fomentera, in the Mediterranean. The whole arc from Dunkirk to Fomentera covers about 12½° of latitude, or about 850 miles. Delambre's base of verification, of about 7.3 miles, differed from its computed lengths by only about 11 inches.

12. The *second* is the great Indian arc, commenced by Colonel Lancton in 1802 at a place called *Punnœ*, near Cape Comorin, the extreme southern point of Hindostan, and extended northward through about 10° of latitude (680 miles.) After the death of Lancton, in 1823, the work was continued by Captain Everest, who had been his principal assistant, through an arc of nearly 11½° (797 miles.)

This whole distance, measured with singular ability, extending from Cape Comorin to the foot of the Himalay mountains, is 1,477 miles.

Two of Everest's bases of verification, of about $7\frac{1}{2}$ miles in extent, differed by computation, the one 4 and the other 7 inches from the measured length.

13. *The third* is the Russian arc, extending from Ismail on the Danube to the Arctic sea near the North Cape, being more than 25 degrees (25° 20′.) The work was under the direction of the able astronomer Strové. It was begun in 1816, and has but recently been completed. The complete discussion of the observations has not yet been given to the public. This arc is about 1,750 miles in extent, and is believed to have been measured with eminent ability.

14. Any sketch of the geodetic operations which serve to determine the figure of the earth would be incomplete without a notice of the United States Coast Survey.

The great interest with which this question was regarded in early times arose from its importance as an astronomical problem; but in the attempts to devise more accurate methods for the measurement of arcs upon the earth's surface, it was found that, for the construction of accurate maps of any extended portions of the earth, a knowledge of its precise figure was not only essential, but that the method of triangulation which was adopted to connect the extreme points of the arc to be measured, together with the astronomical positions of those points, formed the best possible basis of a map of the region traversed by the system of triangles.

This was the origin of the science called geodesy or geodetic surveying. The interest which was felt in the solution of an important scientific question was, therefore, soon merged in that which attended its practical benefits to the human race, in the construction of accurate maps, showing the boundaries of States and provinces, and the configuration of sea coasts.

The French arc was first made the basis of a complete map of France, and most of the measurements of arcs in modern times have been incidental to the prosecution of extended surveys of the territories through which they pass.

The figure of the earth having been approximately determined, the more accurate measurement of its dimensions, from having been the primary object of the great geodetic operations of the globe, has, therefore, become secondary or incidental to geodetic surveys. Thus the Indian arc, the Russian arc, and numerous measurements in Europe, would, perhaps, not have been undertaken, except as the result of extended trignometrical surveys for national purposes.

Every improvement in the construction of instruments for geodetic and astronomical purposes, and in the methods of observation employed, gives additional value and weight to subsequent measurements, and hence it is that the data derived from the geodetic operations of the United States Coast Survey for the more accurate solution of the question of the figure of the earth may be looked for with great interest.

The important objects of this survey, united with the great extent of the coast, requires the highest attainable accuracy in the great

chain of triangles which stretches along the coast, forming the basis of the survey, and in the astronomical determinations connected with it. It has been demonstrated that, in works of this character, ultimate economy is promoted in proportion to the precision with which the work is first executed. There is every demand, therefore, for the most perfect instruments, the most approved methods of observation, and the best practical skill in establishing the true positions of the primary points of the survey.

The American Coast Survey now represents, according to the best authorities, the most perfect forms of practical science applicable to works of this character; and a general sketch of the methods employed in the geodetic operations, in order to illustrate the value of the new measurements of arcs of the earth's surface which will follow the completion of the primary chain of triangles along the coast, will not be out of place in connexion with this subject.

The triangulation of the Atlantic and Gulf coasts when completed will extend diagonally through 19 degrees of latitude and 30 degrees of longitude. The extreme points of this triangulation will be distant from each other, by the general line of the coast, nearly 3,000 miles; the chain of triangles extending from the eastern boundary of Maine to the western boundary of Texas. It will probably be many years, perhaps centuries, before this triangulation will be extended across the continent to the Pacific ocean; but, ultimately, this will undoubtedly come to pass; in the mean while the survey of the western coast of our territory is progressing according to the plan followed on the eastern coast.

The triangulation of the eastern coast is now continuous from Mount Desert, in Maine, to Shalotte inlet, south of Cape Fear, in North Carolina; stretching over more than ten degrees of latitude and as many degrees of longitude, including the coast of ten States, and the greater part of the coast of two others; then, with an interval of about seventy miles, it extends along the coast of South Carolina and Georgia.

Large detached portions of the triangulation of the coast of Florida, Alabama, Mississippi, Louisiana, and Texas have been completed, and a few years only will be necessary to fill the intervals so as to make a continuous chain from the eastern boundary of Maine to the western boundary of Texas.

This triangulation will rest upon ten or twelve principal base lines, measured on different parts of the coast, which afford the double purpose of starting the work at nearly the same time at different points, and for ultimate verification of its accuracy.

The accuracy of the work has been tested by the connexion of several of these bases in the progress of the survey, and the degree of precision attained is so remarkable as to justify a somewhat detailed description of the various processes by which aërial distances of many miles length, and hundreds of miles from the starting point, or base, may be determined by the wonderful applications of geodesy, with but a few inches of probable or possible error.

When it is said that a certain part of this triangulation is completed, it is meant that all the mechanical work in the field for measuring the base lines and the angles, and for determining the latitudes and longi-

tudes by astronomical observation, has been executed, and the computations performed by which the results of the mechanical work are made available. The calculations of the elements of a survey from given data are founded on mathematical formulæ, and are susceptible of rigid accuracy; but the mechanical work in the field depends for its precision upon the means employed, and on the skill and care of the operator. In some of the early attempts, as we have before stated, to measure great distances on the earth's surface, the only means employed was counting the revolutions of a carriage wheel, of known periphery, in travelling over the distance.

When the method of triangulation was invented the line to be determined mechanically was shortened so that, without too much labor, the whole length could be measured by rods or chains; and, finally, an apparatus was constructed especially for the measurement of base lines.

Any simple material of whatever form is liable to change its dimensions with a change of temperature, so that a line measured on the ground by a steel or glass rod, or a chain, would appear to have a different length if measured in summer, from that which it would have if measured in winter with the same apparatus. This was found to be the chief source of error, and although the changes in length of a rod caused by a given change of temperature may be calculated and a correction applied to the measurements, yet for primary base lines a more accurate measuring apparatus was devised, by combining two metallic bars upon the compensating principle, illustrated in the compensation pendulum.

This method was first applied by Colonel Colby, in the ordnance survey of Great Britain. It has been brought to great perfection in this country by Professor Bache in the base apparatus of the Coast Survey.

The great object to be attained in a measuring apparatus of this kind is such a combination or arrangement that the extreme points of the compound bar used as measuring limits shall remain at an invariable distance apart under all degrees of temperature, and even while the temperature is changing.

This is effected in the Coast Survey base apparatus by two bars, one of brass and the other of iron, each a little less than twenty feet in length, placed side by side so as to be capable of independent parallel motion on rollers. At one end, the two bars are firmly attached to each other by means of a block to which they are fastened by screws, the medium of connexion at the other or free ends of the bars is a lever of compensation. The brass bar is attached to the lever by a hinge pin, and the iron bar abuts against the lever, the free end of which is the point that remains fixed during any change in the length of the bars; the points of attachment of the bars to the lever being adjusted at such a distance from the end of the lever that the motion will be about this end as a centre. These points are determined by the relative expansions of the brass and iron, and the cross sections of the bars are so calculated that they will undergo the same changes of temperature from the same source of heat in the same time. The end of the lever of compensation abuts against a small secondary rod or

bar, which is supported parallel to the iron and brass bars, and which is used for making the contact of the two compound bars during the operation of measuring. On the opposite end of each pair of compound bars a corresponding small auxiliary rod is placed, and also a sector for measuring the slope at which the whole bar is placed.

Two measuring bars being made exactly alike as above described, are placed in line upon the ground and adjusted so that the small rods at the end shall be at the same height, the lever end of one opposite to the sector end of the other; the rod at the sector end of the foremost bar is so attached to a small spirit level that by a slight pressure the bubble will be brought to the centre of the level. The rod on the end of the other bar, which we have described as abutting against the lever of compensation, has a sliding motion, which is resisted by a delicate spiral spring; the end of this little rod is terminated by a smooth agate plane surface, and the end of the opposite rod by an agate knife edge. The contact is made by bringing these ends together, the spirit level insuring the same degree of pressure in every case.

This is the general description of the apparatus; the sector is used for measuring the slope of the ground along which the line extends, the resulting angle giving the means of reducing the measurements to horizontal lengths. Each of the compound bars are enclosed in large tin tubes, to protect them from the air and weather and sudden change of temperature, and in use these tubes are supported on trestles made for the purpose.

There are many interesting details of construction which can only be explained by reference to drawings or to the apparatus itself, a full description of which may be found in the Coast Survey Report of 1854.

With the apparatus we have described a distance of a mile may be measured in one day, and a distance of ten miles may be measured with no greater error than a fraction of an inch. The length of each of the compound bars is kept constantly compared during the measurement of a base line with a standard metallic bar, the length of which at a given temperature is known.

The necessity for the greatest attainable accuracy in such operations is apparent, when we remember that any error in the base line will be greatly multiplied in the triangulation depending upon it. The true cause of the erroneous results of the measurement of the first French arc was an error in the base line of Picard, which was subsequently discovered and corrected as before stated.

A base was measured on Kent island, in Chesapeake bay, to verify the triangulation between a base on Fire Island (on the south side of Long Island) and the Chesapeake. The shortest distance between these base lines is two hundred and eight miles, but the distance through the triangulation is three hundred and twenty miles. The Kent Island base, five miles and four-tenths long, was first calculated from the triangulation, which embraces thirty-two triangles. The computed length differed from the length found by measurement only four inches.

On some parts of the coast, where it is desirable to commence the work of the survey in advance of the main triangulation, preliminary

or secondary base lines are measured by means of wooden or iron bars of simple construction; but all such measurements are, in time, superseded by the progress of the primary triangulation.

In measuring the angles of the primary triangulation theodolites of various sizes and construction are employed. The largest instrument of this class belonging to the Coast Survey has a circle of thirty inches diameter. It was designed by Mr. Hassler, the first superintendent of the Survey, and constructed by Troughton and Simms of London. The circle is graduated to five minutes, and may be read to single seconds by means of micrometers. It is provided with a telescope of great power, by which signals many miles distant may be seen distinctly. This instrument is employed principally on the northeast part of the coast, where the lines range from twenty to eighty miles in length. The accuracy of this instrument is such that the probable error of a single measure of an angle is about one second and a quarter; a mean of about thirty measures is taken for each angle.

Another theodolite of nearly similar construction and of twenty-four inches diameter is also employed in the survey. Besides these, smaller repeating theodolites of various sizes are used on different parts of the work.

Various instruments have been employed for the determination of the latitude of the most prominent points of the triangulation, among which may be mentioned vertical circles, repeating theodolites, and especially the zenith sector, designed by Mr. Airy, the astronomer-royal of England; but all, except the last named, have been found liable to considerable errors. The zenith sector is accurate and gives good results, but its great weight and the labor attendant on its use make it less available for such surveys than an instrument called the zenith telescope, designed by Captain A. Talcott, late of the United States engineers. This instrument is designed to measure by means of a micrometer the difference of zenith distances of stars which culminate within a short time of each other and near the zenith, on opposite sides of it. It is portable, accurate, and simple, and is perhaps destined to supersede all others for geodetic purposes.

In the progress of the latitude observations of the survey discrepancies have occurred which can only be accounted for by local irregularities in the figure and density of the earth. These irregularities are still the subject of investigation. For the determination of the longitudes of the various points of the survey every means which science can afford has been resorted to. All the observations obtainable by eclipses, occultations, and moon culminations, made in this country previously to 1844, together with the simultaneous observations abroad, so far as they could be found, have been collected and reduced, and similar observations have since been continued at Cambridge, Philadelphia, Washington, Charleston, and Cincinnati. All these stations being connected by the electric-telegraph, their differences of longitude have been determined with great accuracy, and all the results are referred to Cambridge, as a common station of reference.

The difference of longitude between Cambridge and Liverpool has also been determined by means of large numbers of chronometers

carried repeatedly between the two stations on the Cunard steamships.*

"The differences of longitude between Cambridge and the principal stations of the survey in other sections are determined by the aid of the electric telegraph, wherever this has been established. In this method, which is by far the most accurate for determining difference of longitude, the Coast Survey has taken the lead, and has brought it to a state of perfection which subsequent operations of a similar nature executed in Europe have not yet reached.

"The idea of comparing the local time of different places by means of the electric telegraph is sufficiently obvious, and dates from the conception of the telegraph itself; but the refined methods by which the intervention of human senses and operations, and the consequent liabilities to error, are, in the greatest possible degree, avoided, and by which the time of transmission is measured and eliminated from the longitude, have been the result of careful study and long experience. The method of recording observations of time on a chronographic register, by means of a galvanic circuit, known in Europe as the *American method*, originated in the Coast Survey with the first attempts to determine longitude by means of the electro-magnetic telegraph. The *chronographic record* is made on a cylinder, revolving with nearly uniform velocity, covered with a sheet of paper, upon which a pen traces a line, interrupted or deflected for an instant through the agency of an electro-magnet, every time the pendulum of the clock passes the vertical, and in doing so interrupts a galvanic circuit. Either cylinder or pen are at the same time slowly moving lengthwise, so that the line formed is a long spiral, which is thus graduated into spaces corresponding to seconds of time, and described with uniform velocity. When any instant of time is to be recorded, the observer strikes a finger-key, which also breaks the galvanic circuit and causes a similar mark to be made on the record, the position of which, in reference to the adjacent seconds marks, can be read off with great precision. In the chronographs employed in the Coast Survey a second is generally represented by from one-half to three-quarters of an inch, the cylinder being regulated so as to make one revolution in half a minute.

"By an ingenious arrangement in the clock the break for every sixty seconds or minute is omitted, and every five minutes two breaks are omitted. By this means a whole sheet may be read off without any other note than the time of beginning and ending.

"The method of determining longitudes by means of the electric telegraph is substantially and in brief as follows: A transit instrument, astronomical clock, and chronograph are mounted at each station. After suitable observations for instrumental corrections at each station, which are recorded only at the place of observation, the clock at the eastern station is first put in connexion with the circui so as to write on the chronographs at both stations.

* The preceding account of the details of the operations of the Coast Survey has been furnished by Professor Trowbridge, and what follows is copied from the report of a committee of the American Association for the Advancement of Science.

"A number of stars, culminating near the zenith of the two stations, are selected by the observers. As they appear first upon the eastern meridian their transit is recorded by the observer striking the finger-key upon the chronographic registers at both stations. After an interval of time equivalent to the difference of longitude between the two places, which is measured by the clock, the same stars appear on the western meridian, and the observer at that station records this transit precisely as the other had done, and the difference of the two records of time is the measure of the difference of longitude.

"It will be observed that these records have been obtained at both stations, and a little reflection will show that if there be any sensible interval of time consumed in the transmission of signals, the difference of longitude obtained from the record at the eastern station will be too great by that interval, and that at the western station will be too small by the same amount. The mean result will give the longitude free from this error, and the difference of measure the time of transmission of the signals through the whole circuit.

"Ten stars are generally exchanged with the eastern clock in the circuit, and, after the first five, the transit instrument is reversed so as to eliminate any residual error in the correction for collimation. The western clock is next put on and the same operation repeated with ten other zenith stars. Not only is the result improved by the accumulation of individual results, but the advantage is gained that the interval is measured by another clock, and the time of transmission eliminated in the inverse order of effects. The transits of the stars are generally recorded over fifteen wires. After the exchange of signals by the second clock is completed, local observations for instrumental corrections are again made, which conclude the night's work. These operations are repeated on, at least, three different nights, after which the observers and instruments exchange places, so as to eliminate the possible errors arising from causes connected with their individual peculiarities.

"By the perfect and admirable method just sketched we are able to measure arcs of longitude with the same degree of accuracy with which arcs of latitude have heretofore been ascertained, and a new element has thus been introduced into geodesy. Since the general introduction of the electric telegraph and the development of the American method of longitudes it has been applied to many of the older European geodetic surveys; and, in general, a very full acknowledgment has been made of their indebtedness to American science by the eminent geometers having charge of such works.

"It was one of the earliest discoveries resulting from the telegraphic determinations of longitude that the time transmission of signals between stations several hundred miles apart is quite sensible, and that it appears, in a great degree, to depend on the distance. On the telegraph lines used in this country, where large iron wire is employed, and the circuit is completed through the earth, the rate of transmission has been found to be from 11,000 to 20,000 miles per second. Whether this actually was the velocity of the galvanic current, or whether it rather measures the time during which the current must

be established in order to produce the effects that we observe, is for the present an unsolved question.

"The *telegraphic* determinations of longitude have been extended from Washington northward to Philadelphia, New York, Cambridge, Bangor, and Halifax, and southward to Petersburg, Wilmington, Charleston, Savannah, Mobile, and New Orleans.

"Great credit is due to the public spirit of the telegraph companies, who have extended every facility to the operations of the Coast Survey, and have given the use of the line after working hours free of charge.

"In sections of the coast to which the telegraph has not yet penetrated, such as Florida, Texas, and the Pacific coast, the longitudes of cardinal points are determined by observations of moon culminations and by chronometer.

"Corresponding observations of moon culminations are made at several American observatories, at the expense of the Coast Survey; and most valuable aid is derived from the series of meridian observations of the moon made at Greenwich, which are always most promptly obtained through the kindness of the astronomer-royal. The manner in which the reductions are made to keep pace with the observations at the latter observatory is admirable, and worthy of general imitation.

"The chronometric determination of longitude between Savannah and Fernandina, in Florida, the details of which have been communicated to the American Association at the Montreal meeting, may serve, in plan of execution and mode of discussion, as a model for operations of a similar character.

"The triangulation of the eastern States will furnish a measurement of one arc of meridian of over three degrees in length between the island of Nantucket and Mount Blue, in Maine; another of equal extent along the Chesapeake Bay and southward; and, by the admirable method of determining differences of longitude by the electric telegraph an arc of parallel of latitude embracing over ten degrees of longitude, may be measured along the Gulf of Mexico."

These measurements cannot fail to be of great importance in establishing correct values for the elements of the earth's dimensions, and the result will be one of those valuable contributions to science which attend the thorough prosecution of works of this character.

The results of all the measurements in different parts of the earth indicate a lengthening of the degrees as we go towards the pole; but there are many discrepancies, some, no doubt, the result of the imperfection of instruments and the unavoidable error of observation. But there are still others which are not probably traceable to these sources. They clearly show that the earth is flattened at the poles, but they also show it has irregularities of figure which are not yet fully explained. If we take the mean results of all the best measurements, we have for the length of a degree at the equator 68.7 miles, nearly 362,626 feet; at the arctic circle, 66° 20′, 69.4 miles, nearly 365,744 feet; difference 3,118 feet.

15. With the measured length of the degrees it is easy to obtain the exact figure of the earth.

Thus, fig. 5, if A B is a measured arc of one degree near the pole,

the plumb-line at the two extremities will not meet at O, the centre of the earth, but at C, some distance below. We may now suppose A B to be an arc of one degree upon the circle whose radius is A C. That being supposed, we shall readily know the whole circumference, which is 360 times A B; and knowing the circumference we can readily find the radius, A C, which is known as the *radii of curvature*. And by this is meant that the arc A B will coincide with a circle drawn round C as a centre, and A C as a radius, more nearly than with any other circle which can be drawn.

Assuming the meridian curve to be an eclipse with two radii of curvature, we can compute the two semi-axes of the figure N O and O E. The ratio of these two, the polar and equatorial radii, gives the oblateness or ellipticity.

Professor Airy, some years ago, selected thirteen of the most reliable arcs, and from the combinations, two and two, deduced the probable value of the polar and equatorial diameters, as follows:

Polar diameter in miles........................	7899.17	Radii 3949.58
Equatorial diameter in miles.................	7925.65	" 3962.82
Difference..................................		13.24

More recently, Bessel, selecting eleven arcs, some of them the same and others different from those of Airy, by widely different methods computed the values, as follows:

Polar diameter in miles........................	7899.11	Radii 3949.55
Equatorial diameter in miles.................	7925 60	" 3962.80
Difference..................................		13.25

It is not a little remarkable that results based upon different measurements and computed by different methods, and in both cases, as Sir John Hershel remarks, "the mass of figures to be gone through with being enormous,"—I say it is most remarkable that the difference in the length of the earth's radius, as determined in the two cases, should be less than the $\frac{2}{100}$ part of a mile. Any residual error which may affect these results must be extremely small.

We then have for the figure of the earth a spheroid flattened at the poles to such an extent that the polar radius is $13\frac{1}{4}$ miles shorter than the equatorial. This difference divided by the equatorial radius gives the *oblateness* or *ellipticity*. It comes very near to $\frac{1}{300}$, more exactly $\frac{1}{299.1}$. This variation from perfect sphericity in a 20-inch globe could scarcely be detected by the most accurate eye, and yet this oblateness of the earth enters as an essential element into many of the most important and curious problems in astronomy. The equatorial circumference of the earth is 24,886 miles. It is proper to remark, in

conclusion, that there are so many discrepancies in the results of these computations as to force upon astronomers the conviction that the figure of the earth is not that of a spheroid of revolution. There must be in different portions of the surface local depressions and elevations which are most probably due to unequal densities in the interior. The surface, strictly speaking, is warped and irregular. But these irregularities, though capable of being detected, are very small.

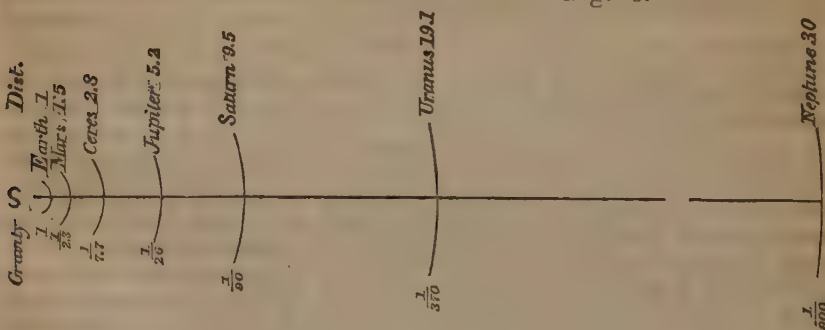
Such are the results of two centuries of arduous scientific labor upon the figure and magnitude of the earth; labor in the field and in the study, which has put in requisition the utmost skill of mechanic arts, and exhausted the resources of mathematical analysis.

LAW OF GRAVITATION.

In my previous lecture I endeavored to explain the method of finding the *exact figure and magnitude of the earth.*

1. I shall this evening call your attention to the law of gravitation. This may be termed the great law of the material universe. There is no single law of nature which reveals so much, none which controls and determines so many physical conditions and events, none which carries us so far into the distant future, or conducts us back so far to contemplate the past. This law determines alike the fall of a pebble, the mighty swell of the ocean, and the vast sweep of the comet, coursing its fiery track of a thousand years. It guides every planet in its orbit round the central sun, and, in the midst of inevitable and endless perturbations, guarantees the final stability and harmony of the system. In its immense range of applications it invites to the sublimest contemplations of which the human mind is capable.

Fig. 6.



2. The law of gravity may be stated as follows, viz: *every particle of matter attracts every other particle by a force proportional to the mass, and inversely as the square of the distance.*

Each separate body in the system attracts every other body by the same law. The earth, for instance, has a fixed mass; it attracts the moon and the sun, and each of the planets, by a force proportional to its mass, and inversely as the squares of their respective distances. To illustrate this law, as it applies to the solar system, let S in fig. 6 represent the sun.

Suppose the planets placed at their relative distances, the earth's distance being unity, then the figures in the upper part of the diagram will represent the relative distances of the other planets, viz: Mars 1.5, Ceres, as the mean of the asteroids, 2.8, Jupiter 5.2, Saturn 9.5, Uranus 19.1, and Neptune 30. The force of the solar attraction upon them will then be represented by the figures on the lower part of the diagram, which are inversely as the squares of the distances. The attraction on the earth being 1, on Mars it will be $\frac{1}{2.3}$, on Ceres $\frac{1}{7.7}$, on Jupiter $\frac{1}{26}$, on Saturn $\frac{1}{90}$, on Uranus $\frac{1}{370}$, and on Neptune $\frac{1}{900}$. If their orbitual motions were stopped, the earth would move toward the sun 900 times as fast as Neptune.

This enables us to form a true conception of what this law is. Of the nature of gravity itself we know nothing. We give the name of law to the effects which it produces. Everything connected with the history and progress of so grand a principle in nature must awaken a special interest. Any law or principle which enables the astronomer to determine, not with uncertainty and vague conjecture, but with the utmost precision, the relative position of the heavenly bodies for ages past and for ages to come, challenges our admiration. The astronomer turns his telescope to the heavens and watches the progress of the stars as they enter and cross his field of view, and marks the hour, minute, and second when one of them disappears for an instant behind a spider's web which is stretched across his field of view. Suppose the telescope to stand unmolested, it is not difficult to predict the hour, minute, and second when the same star will disappear behind the same spider line after the lapse of a hundred years. The earth will, in the mean time, have made a hundred revolutions around her orbit of nearly 600,000,000 of miles, but the force of gravity will have kept her in her appointed track. She pursues her elliptic course without weariness or change.

3. But let us glance at the history of the discovery of this great law. Speculations upon the causes of the heavenly motions were probably coeval with the observations which served to make them known. Many of these speculations which have come down to us are characterized by great crudeness, but they all show the perpetual tendency of the human mind to ascend from phenomena to their causes.

The earlier Greek astronomers introduced a system of *crystalline transparent spheres*, revolving one within another, and carrying the planets with them round the earth as a centre. Far beyond these crystalline planetary spheres was the "*primum mobile*," *the starry sphere*, revolving from east to west in twenty-four hours. This system was incorporated into the philosophy of Aristotle, and seems to have commanded the assent of mankind for many ages. Its truth was hardly drawn into doubt till the revival or commencement of true

astronomical science in the seventeenth century. And even then the clearest and strongest intellects were slow in extricating themselves from the trammels of the Aristotelian philosophy.

It was not until the time of Kepler that any real progress was made in discovering the true laws of planetary motion. He discarded all dependence upon authority. His views were independent and bold, but in many respects extremely defective and often whimsical. Yet his labors will ever be regarded as forming a brilliant epoch in the history of astronomy.

It is true that Copernicus had established the true system of the world, which fixes the sun in the centre; Galileo had demonstrated the laws of motion, in falling bodies, and laid the foundation of dynamical science; Tycho Brahé had, for a quarter of a century, most diligently watched and recorded the motions of the heavenly bodies. But neither of these illustrious astronomers had ventured any hypothesis for explaining the cause of those motions.

By the laborious comparison of the observations of Tycho, Kepler discovered the three laws of planetary motion which bear his name, and which constitute the ground work of physical astronomy. They are familiar to every student. The first is, *that the planets revolve in elliptical orbits;* the second, that *the radius-vector, or the line drawn from the sun to the planet, describes equal areas in equal times*, in whatever part of the orbit it is located; the third, that *the squares of the periodic times are proportional to the cubes of the mean distances.* This third law may justly be regarded as one of the grandest inductions in the whole range of physical science. But Kepler was still far from having any just conception of the *true physical cause* of these motions.

He rejected the crystalline spheres of the Greeks and located in the sun a kind of *central virtue*, by which the planetary motions were maintained. But this *force* or *virtue*, for he uses both terms, must have the effect, as he perceived, not of drawing bodies directly *toward* the sun, but of moving them *across or athwart* this line of direction. It must, in some way, carry bodies *round* the sun.

In order to render this idea plausible he was obliged to introduce a *whirling fluid* which bore the planets round in the same manner that a running stream carries a boat. This was substantially the same hypothesis which, nearly half a century later, was propounded by Des Cartes, and was known as his celebrated *system of vortices.*

But, in addition to his other agencies, Kepler gravely believed and taught that each planet was animated by a spirit which held to the matter of the planet a relation analogous to that which the mind of man holds to his body. This great *animal spirit* acted an important part in giving to the planet the right direction.

Nor can we be much surprised at this fancy when we find even the great Newton gravely recording his suspicion, as he does in his Principia, that "the spirit which constitutes the most subtile and best portion of our atmosphere, and which is necessary to all life, is derived from comets."

But, unsuccessful as Kepler was in discovering the true physical cause of the planetary motions—the law which was underlying his

laws—he gave a great impulse to the spirit of inquiry. The energies of all the ablest mathematicians and astronomers of the age were concentrated upon this problem.

In the mean time other branches of science were throwing light upon this. Gilbert, of England, had investigated the laws of magnetism, and in 1600 had published a work, remarkable for that period, on the magnet. This work was known to Galileo and Kepler, and was much esteemed by them. The attraction between two magnets suggested the idea that some analogous force might exist between other bodies. Gilbert explained the influence of the earth upon the moon by regarding the earth as a great loadstone. In like manner, he supposed the moon to have a reciprocal action upon the earth, not only upon the matter of the earth but upon "certain subterranean humors and spirits" which are drawn out and modified by the moon's action. Galileo and Kepler, as Grant says, both professed themselves to be much indebted to the views contained in Gilbert's work upon the magnet.

Kepler fully adopted the principle of some sort of attraction, but how that force acted in maintaining the orbits he did not comprehend. His great work on astronomy, the "Astronomia Nova," was published in 1609. In this work he maintains that some sort of attraction exists between all the planets of the system, and that the planetary motions are maintained by some sort of influence emanating from the sun. He seemed to be constantly impressed with the idea that a *centripetal* force alone would not keep a planet in motion. It must have some force either *pulling* it or *pushing* along in its course. And hence he was obliged, on this hypothesis, to make the sun-force propel a planet in a direction perpendicular to the radius-vector.

We may judge how slow was the progress of true ideas upon this subject from the fact that the law of gravitation was not discovered till considerably more than half a century after the publication of Kepler's work, before mentioned.

In the mean while the law of planetary attraction engaged the attention of Galileo, of Borelli, of Boulliau, of Des Cartes, Cassini, Huyghens, Hooke, Halley, Sir Christopher Wren, and finally of Newton. Among these Christian Huyghens, by common consent, is second only to the illustrious Newton. Huyghens, who preceded Newton by a few years published a very remarkable work in 1671 on the pendulum. In this work, entitled "De Horologio Oscillatorio," he inserts several important theorems respecting the motion of a heavenly body, which is constantly drawn to a fixed centre. Borelli, of Pisa, had, a few years before, (1666,) published a work in which he quite accurately describes the action of centrifugal and centripetal forces, and shows that they would together cause a body to revolve in a circular orbit.

At this time, 1665, when Newton's attention was first drawn to the subject, it had become a common opinion, though by no means a universal one, that the planets were retained in their orbits by a force residing in the sun. And the great point at issue now was to determine what kind of an orbit it would produce, and how it varied with the distance; whether it was inversely as the distance, or inversely as

the *square of the distance*, or whether it varied in some more complicated ratio of the distance.

Bouilliau,* a French astronomer, cotemporary with Newton, though older, is said to have been the first to suggest the *inverse ratio of the square of the distance* as the law of variation, which he did in 1645. Kepler maintained the opinion that the variation was inversely as the distance simply. Hooke made the announcement that he had demonstrated the law to be as the *square inversely*, but declined showing his demonstration, and it finally appeared that he never had one. It, indeed, seemed to be the prevailing opinion that the force must vary inversely as the square of the distance. Wren concurred in this opinion, but he could give no proof. Halley was in the same predicament. They had both made the question a subject of special study. Huyghens had once adopted this view of the question, but failing to find any satisfactory proof had rejected it. Such was the state of the problem when Newton entered upon its investigation. The progress and result of his inquiries will always possess a singular interest in the history of astronomy.

It was in the summer of 1665, when the breaking out of the plague in Cambridge had forced Newton to leave the place, that he retired to his native village of Woolsthorpe. Witnessing the fall of an apple, as the story is usually told and sanctioned by Brewster, he conceived the idea that this same terrestrial gravity which caused the apple to fall, and which certainly extended to the highest attainable elevations, might extend even to the moon, and be the force which retained her in her orbit. To produce this effect there must be a certain determinate force directed towards the earth, acting constantly upon the moon, and deflecting her from a right line into the curve which forms the orbit. With the distance of the moon and the velocity of revolution this force could easily be computed. It only remained to see whether the terrestrial gravity at that distance was sufficient to produce precisely that effect.

The principle upon which this conclusion rests will be readily understood by reference to figure 7. Let E be the earth, M B a portion of the moon's orbit, and suppose that M B is so small a portion as to be passed over by the moon in one minute of time. It was a well established principle in mechanics that any body moving in a curved line tends to recede from the centre, and if not constantly restrained by some force, to move in a straight line tangent to the curve. Thus if the attraction of the earth should be suspended at the instant the moon reached the point, she would move in the straight line M O and not in the curved line M B. Now, if we

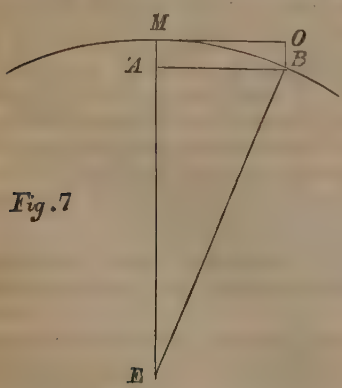


Fig. 7

* Written also *Bouilland* and *Boulliand*, born 1605, died 1694.

suppose the velocity of the moon to be such as to carry it from M to O in one minute, how large a force directed towards the earth would be necessary to make it move in the arc M B? If we construct a parallelogram having M O for one side, M A for another, and M B (considered as a straight line) for its diagonal, then M A must be the measure of the force necessary to keep the moon in her orbit. But this line M A is the versed sine of the arc M B. Hence we know, and this was Newton's mode of investigation, that the force, whatever it is, which retains the moon in her orbit must be directed to the earth, and must be such as to cause a body to fall through the versed sine of any small arc in the same time that the body is actually occupied in describing that arc. Now, the distance of the moon being known, as it was proximately, and the time of revolution being also known, it was easy to compute the length of the arc passed over in any small portion of time and also its versed sine. Hence the distance M A becomes a known distance. A body at the earth's surface falls through a known distance in one minute. Call this distance h and let R be the radius of the earth, and D the distance of the moon, and x the distance through which the earth's attraction would cause a body to fall if placed at the moon, then we should have $D^2 : R^2 : : h : x$. To answer the required purpose, x must equal M A. This was Newton's course of reasoning.

Taking the measure of a degree on the meridian to be 60 miles, as determined by Fernel, and then generally adopted, he deduced the earth's radius, and then found, by making the calculation, that the attraction of the earth at the distance of the moon was insufficient to produce the required effect. It equally failed whether it was supposed to vary inversely as the *distance* simply, or as the *square* of the distance. And the difference was too great to be attributed to any error in the calculation, or in the moon's motion.

In the spirit of true philosophy he rejected the hypothesis which was insufficient to account for the facts. And, singular as it may appear, he seems, from anything now known of his labors, to have dropped the investigation for nearly twenty years.

The measurement of arc of the meridian, in France, by Picard, which gave a more correct measure of the earth's radius, recalled his attention to the subject. And repeating his calculation with this corrected measure, he had the satisfaction of finding that with the inverse ratio, the square, the intensity of the terrestrial gravity was almost precisely that which was required in order to keep the moon in her orbit. This was the "experimentum crucis." The great law of nature was established.

We now know that the mean distance of the moon is very nearly 60 times the earth's radius. The terrestrial gravity varying according to this law, it will at that distance be $\frac{1}{3600}$ part of what it is at the earth's surface. Hence a body at the moon will fall through the same distance (16.1 feet) in one minute, that it will fall at the earth's surface in one second. And this is almost precisely the versed sine of the arc for one minute described by the moon's mean motion.

A like test was applied to the planets as influenced by the attraction of the sun, and the same law was found to obtain.

The final verification of the law of gravity is, that it predicts the disturbing effects which one body must have upon another.

With this law in his hand the astronomer in his study has predicted inequalities in the planetary motions which no observer had detected, and many which, though real, were too small to be detected till they were pointed out and made the subject of special observation.

The attention of Newton was particularly called to the law of gravitation in 1665. The Principia, in which his discoveries were given to the world, was not published till 1687. The doctrines which he announced were slow in winning their way to scientific favor. Out of England, for a period of nearly forty years, they were either not known or were known only to be rejected. The theory of vortices, as promulgated by Des Cartes, had obtained great popularity on the continent, and was adopted by most of the eminent continental astronomers of the age.

Huyghens adopted the Newtonian doctrines only in part. Leibnitz and John Bernouilli were conspicuous in opposition to them. Cassini and Miraldi, to the end of their lives, were borne along by the vortices of Des Cartes. "On the continent," says Grant, "all the great mathematicians were unanimous in their hostility to the Newtonian theory." At length, in 1732, forty-five years after the publication of the Principia, and five after the death of Newton, Maupertuis, of the French Academy, was the first to adopt and defend the doctrines of the Principia. But the writer who did most to commend the Newtonian theory to favor in France was, probably, Voltaire, who, in 1738, published a brief, popular exposition of Newton's work, which was widely circulated and did much to conciliate the favor of the learned to the views of the great English philosopher. But if the French astronomers in the first instance sinned against true science in rejecting the doctrine of Newton, the labors of Clairault and La Place have made ample atonement for it since. The theory of Newton is universally received; the vortices of Des Cartes survive only as a memorable example of scientific error.

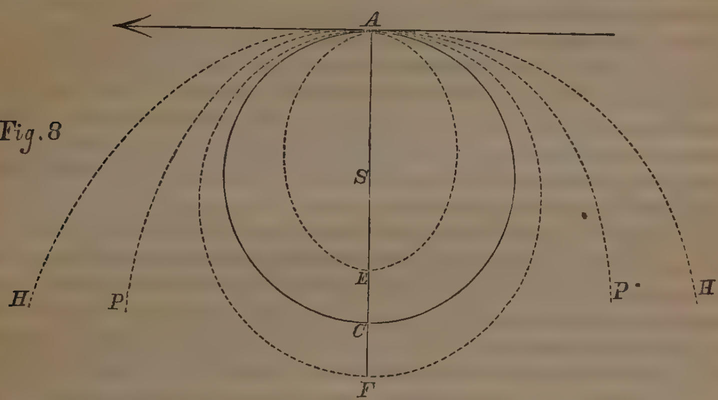
Having given a sketch of the history of the law of gravitation, I must content myself with adverting to two or three illustrations.

1. What kind of a curve may a heavenly body describe, under the action of this law?

Newton showed that the curve might be a *circle*, an *ellipse*, a *parabola*, or a *hyperbola*, being the four curves made by the section of a cone, and it could not revolve in any other. Thus, in figure 8 let S represent the place of the sun, and let A represent any body placed at any given distance, as at A. Now suppose it receives an impulse in a direction perpendicular to the radius-vector S A, the form of the orbit which it will describe will depend upon the intensity of this impulse. Any impulse in that direction will produce a centrifugal force. If this centrifugal force is exactly equal to the centripetal force of the sun, the body will describe a *circle*, A C, about S as a centre; if it receives a less impulse it will describe an *ellipse*, as A E, of which A is the aphelion and S the remoter focus; if it receives a greater impulse it will still describe an *ellipse*, as A E, of which A is the peri-

helion and S the nearer focus. If we now suppose the impulse to grow stronger and stronger, the ellipse will become more and more elongated, the aphelion E receding farther and farther, until the curve changes into a *parabola*, and the two branches never meet. The particular impulsive velocity necessary to produce a parabola is that which a body would acquire under the action of the sun in falling from an infinite distance. This velocity would not be infinite. The

Fig.8



velocity due to an infinite distance is finite, and hence might be increased. Any increase of that velocity would cause the body to move in a hyperbola, as A H. One impulsive velocity only will produce a circle, one only a parabola; an infinite number an ellipse, an infinite number a hyperbola. Hence the antecedent probability of a truly circular or parabolic orbit is only as one to millions, while the probability of an elliptical or hyperbolic orbit is as millions to one. And this accords with the facts of astronomy, so far as they are known.

2. The secular acceleration of the moon's mean motion in longitude. By the comparison of some ancient eclipses with their computed times, Halley, as early as 1693, suspected an acceleration in the moon's mean motion, but the question was not fully investigated till half a century later, when more accurate calculation placed the fact beyond all doubt. In 1749 Dunthorne presented to the Royal Society of London an elaborate paper upon the subject, in which he determined the acceleration to be *ten seconds* in a hundred years, reckoned from 1700; that is, the mean motion being taken, the moon arrives at the meridian of any fixed star ten seconds *sooner*, at the close of a century, than she would if her mean motion had continued the same as it was at the beginning of it. And, as a consequence of this, she would come to the meridian of any particular place ten seconds *later* than she otherwise would. The recent profound researches of Hansen, of Seeberg, upon the lunar irregularities have led him to adopt 13 seconds as the secular acceleration. "The moon," says Grant in his excellent History of Physical Astronomy, "is about two hours later

in coming to the meridian than she would have been if she had retained the same mean motion as she had in the time of the earliest Chaldean observations." If we adopt the new coefficient of Hansen, 13″, it will increase the difference by about half an hour. Hence, in assigning the moon's place in any remote period in the past by the use of the modern tables, the assigned place will be *less* advanced in longitude than the actual place. The accurate determination of this coefficient of acceleration is of the utmost importance in verifying the ancient eclipses.

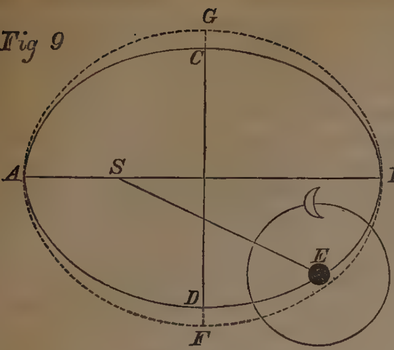
The cause of this acceleration for a long time baffled the severest scrutiny. The French Academy offered its astronomical prize of 1770, 1772, and 1774, for an investigation which should have for its object to show whether it could be produced by the law of gravitation. The first prize was taken by Euler, the second was shared by Euler and Legrange, the third was awarded to Legrange alone. Both of these eminent mathematicians concurred in the conclusion that it could not be produced by the action of gravity. The language of Euler in the memoir which bore off the prize is very explicit, as follows: "There is not one of the equations about which any uncertainty prevails, and now it appears to be established by indisputable evidence that the secular inequality in the moon's mean motion cannot be produced by the forces of gravitation." The failure of Euler and Legrange in attempting to trace this inequality to the effect of gravity, and the great weight of their authority, may have deterred others from repeating the investigation, and turned their attention to some other quarter for a solution.

Newton was inclined to refer it to the resistance of the medium in which the moon moved, and his conclusion—the only one, indeed, which his premises permitted—was, that the moon was winding in toward the earth, and must ultimately fall upon it.

But the profound analysis of Laplace, in 1787, revealed what had escaped the sagacity of Newton and Legrange. He traced it to a very slow and almost imperceptible change in the form of the earth's orbit, technically called the secular diminution of the eccentricity of the earth's orbit.

The general manner in which this inequality is produced is not difficult to be understood. One of the consequences of gravity deduced by Newton was, that the disturbing force of the sun's attraction upon the moon had the effect to diminish the gravity of the moon to the earth by about $\frac{1}{360}$ part of it. If the earth and moon were removed to a greater distance from the sun the consequence would be that the moon would be drawn down nearer to the earth, and would make her revolution in a shorter time, because, with an unchanged actual velocity, she would revolve in a smaller orbit. Now, this is precisely the effect of the diminution of the eccentricity of the earth's orbit. Thus, in fig. 9, let A C B D represent the earth's orbit, S the place of the sun, A B the major axis, and C D the minor. The form of the orbit has been for many ages undergoing a gradual change, almost imperceptible, but still continuous. This change is due to the disturbing action of the planets upon the earth, and is one of those

Fig 9



periodic inequalities which stretches over an immense cycle of ages. The nature of this change will be readily seen by a reference to fig. 9. A B, the major axis, remains always the same, while C D, the minor axis, increases in length, and the sun comes nearer to the centre. If we suppose the full line, A C B D, to represent the orbit as it was some ages back, the broken line, A G B F, will represent it now. The earth and moon, by being carried into a wider curve, are less affected by the disturbing force of the sun. The earth's power upon the moon becomes relatively increased, and hence, as before stated, the gradual acceleration.

The eccentricity of the earth's orbit is now about 0.0168; that is, the distance from the centre to one of the foci is $\frac{168}{10000}$ part of the mean radius. Leverrier, in a remarkable memoir upon the secular variations of the orbits of the seven principal planets, has shown that the eccentricity of the earth's orbit will continue to diminish for about 24,000 years, when it will be reduced to 0.0033, or about $\frac{1}{5}$ of its present value. It will then begin to increase, and will go on increasing for many thousands of years. The moon will then begin to wind *out* instead of winding *in*, and will enter upon her appointed but immense cycle of *secular retardation*. The anticipated catastrophy of a collision between the earth and moon will be happily prevented.

3. I select as a third illustration the discovery of the planet Neptune. This will ever be regarded as one of the grandest achievements of science.

The planet Uranus was discovered by the elder Herschel in 1781. On searching the records of previous observers it was found that the planet had been observed and its place recorded *nineteen* times before it was suspected to be a planet. By this means it was possible to determine the orbit and construct tables much sooner than could otherwise have been done. The French Academy made its orbit the subject of a prize in 1790. Delambre was the successful competitor. He subsequently computed tables of this planet. It was pretty soon found that Delambre's tables did not well represent the observed places of the planet. These inequalities were so great that new tables were computed by Bourvard in 1821. But these, again, in a few years, were found to be nearly as defective as Delambre's, and required correcting. From 1795 to 1822 the observed longitude was in advance of the computed. The planet then fell back till 1830 and 1831, when the observed and computed longitudes agreed. The observed place then rapidly fell behind the computed place. The error of the tables in giving the geocentric place, in 1835, was 30″; in 1838, 50″; in 1841, 70″. The attempt further to correct the elements as given by

the tables soon revealed the fact that no orbit could be assigned which would harmonize the observations. Bourvard himself was the first to suggest that the motion of Uranus might be disturbed by an *unknown planet* outside of it. This soon became the prevailing impression among astronomers. So confident had astronomers become of its existence that just two weeks before its discovery Sir John Herschel, in addressing the British Association at Southampton, (September 10, 1846,) says, "its movements have been felt trembling along the far-reaching line of our analysis with a certainty hardly inferior to occular demonstration."

Supposing such a planet to exist, the problem of determining its position was one of extreme difficulty, yielding only to the very highest powers of mathematical analysis. It would seem that but few astronomers in Europe had the hardihood to engage in the enterprise. The illustrious Bessel had it in contemplation, but death removed him too soon from the scene of his labors and left the task to other hands.

The problem, as is well known, was oslved, separately and almost simultaneously, by two youthful astronomers, Adams and Leverrier, "*par nobile fratrum.*" Leverrier was the first to announce his result. He wrote to his friend Dr. Gallè, of Berlin, assigning the place of the new planet. "Turn your telescope," said he, "to that point, and there you will see it." The letter was received in Berlin on the 23d of September, 1846. On the same evening Dr. Gallè turned his telescope to the point designated by Leverrier, and both he and the veteran Enkè saw a star of the eighth magnitude in a position where no star was laid down in Dr. Brenicker's chart, then recently published by the Berlin Academy. It was the veritable planet which had so long had a finger in disturbing the good order of Uranus. The heliocentric longitude of the new planet, as fixed by Leverrier, was 326° 0′. That assigned by Adams, without any knowledge of Leverrier's work, was 329° 19′. The same, deduced from Dr. Gallè's observation, was 326° 52′, being within a single degree of the place assigned it by the computation of Leverrier. Never had science a prouder triumph than was achieved on that memorable night.

On examining the record of Lalande, it was found that he had twice observed this planet as a star, viz: on the 8th and 10th of May, 1795. I may remark, in closing, that the first computation of the orbit of Neptune was by an eminent American astronomer, the late Sears C. Walker, and that Professor Pierce, of Harvard University, solved the inverse problem, namely, that of deducing from the data the perturbations which Neptune ought to produce on the planet Uranus.*

SOLAR PARALLAX AND PLANETARY DISTANCES.

In the two preceding lectures I have considered the *figure and magnitude of the earth* and the *law of gravitation*. I shall this evening call your attention to the method of determining the *solar parallax* and *planetary distances*.

One of the first wants of astronomy was, to ascertain the distances of the moon, sun, and planets from the earth. It was long, however, before any considerable progress was made in the solution of this important problem. The first and indispensable requisite for solving

* Smithonian Report for 1853, page 161.

it, viz: the size of the earth, was wanting. The instrumental means known to the ancients were insufficient to furnish the elements of the calculation.

Aristarchus, of Samos, in the third century before the Christian era, instituted observations for the purpose of determining the relative distances of the sun and moon from the earth. He wrote a treatise upon the subject which has come down to modern times. His method was to observe the angular distance of the moon from the sun at the time when the moon appeared just half illuminated. This method, as a preliminary one, is ingenious, and worthy of a passing notice. Thus, in figure 10,

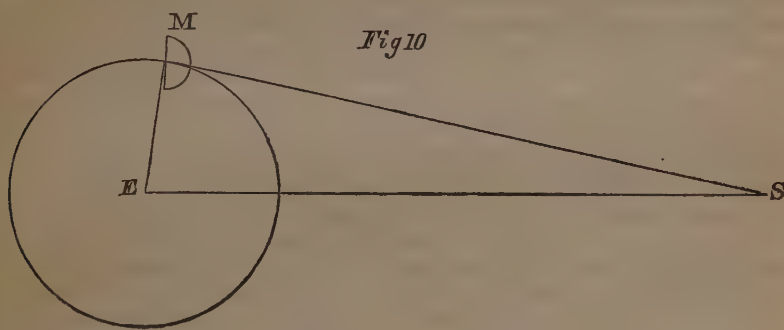


Fig 10

when the one-half of the moon is illuminated, the angle E M S will be a right angle. If the angle M E S is accurately measured, the angle at S will be known, and we shall have this proportion:

$$EM : ES :: \sin. ESM : \sin. EMS = 1.$$

This was the substance of Aristarchus' method. The lines of the angles are known, and this makes known the relative distances of the sun and moon.

The measurements of Aristarchus must have been very inaccurate. He concluded that the sun was nineteen times more distant than the moon. We now know the sun to be about four hundred times more distant than the moon, which shows how extremely wide of the truth this ancient determination was; and yet Ptolemy, four centuries later, adopted the determination of Aristarchus, and, combining it with observations of his own, or more probably those of Hipparchus, computed the sun's parallax to be three minutes, which is more than twenty times its true value. The parallax of *three minutes* would place the sun at only one-twentieth of its real distance. This conclusion of the great Alexandrian astronomer appears to have been adopted down to the time of Kepler, including Copernicus and Tycho Brahè. Kepler's researches on the orbit of Mars led him to conclude that the sun was at least *three times* more remote than Ptolemy had supposed.

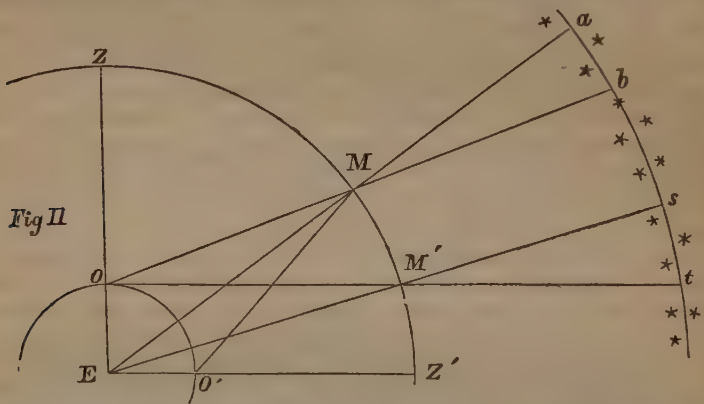
But it is time to explain the method by which modern astronomers have determined the distances of the planetary bodies within narrow limits of error. And here it may be remarked that the *relative* distances of the planets from the sun were quite accurately known long

before any *absolute* distance was determined. The periodic time of the several planets was very easily and very early known. And Kepler's Third Law at once determined all the relative distances. Taking the earth's distance from the sun as the unit of measure, we readily obtain all the others in terms of this by the following proportion:

$P^2 : p^2 :: 1 : d^3$; in which P represents the periodic time of the earth, p that of the planet, and d the distance of the planet, which is the only unknown term.

The radius of the earth being known, the absolute distance of a body is determined by its parallax. This depends upon the solution of a plain triangle, and, in point of principle, the problem is precisely the same as that of determining the distance across a river by means of measurements made on one of its banks. Thus, in fig. 11,

Fig 11



if we suppose E to be the earth, M′ the moon in the horizon as seen from the station O, then O M′ E will be the horizontal parallax. Now, if this parallax is known, which is simply the semi-diameter of the earth seen from the moon, then knowing E O the radius of the earth, and the right angle E O M′, we have in the triangle E O M′ all the angles and one side to find E M′ the distance of the moon, which is done by the proportion:

Sin. E M′ O : radius : : E O : E M′, in which the first three terms are known.

Again: Suppose the moon to be at M, let O and O′ be two stations in the same meridian, whose latitudes are known, which makes known the angle at the centre O E O′. The object is to find the distance E M. To do this, we want the observed zenith distances Z O M and Z′ O′ M, which will make known their supplements E O M and E O′ M; then in the quadrilateral figure E O M O′, having already three of the angles, we can easily obtain the fourth O M O′, by subtracting the sum of the three, which are known, from four right angles. With all the angles and the two sides E O and E O′ it is a simple trigonometrical problem to compute the distance E M. The radii of the earth being known, the only error in the result will depend upon the determination of the latitudes and the zenith distances. But, with the instrumental means now at command, these errors are extremely small. The angle O M O′ may also be determined by observed distances

of the moon from some star in the vicinity. This method is applicable to the moon, to Venus in conjunction, and to Mars in opposition. We shall again have occasion to refer to it. The strict mathematical treatment of the subject is quite elementary, but, to avoid tediousness, I shall omit further reference to it.

The moon's mean distance from the earth is found, by measurements of this kind, to be very nearly 240,000 miles. Herschel gives, more exactly, 237,000.

But the great problem is, to determine the distance of the sun from the earth. This, which gives the means of expressing the distance of all the planets in miles, the British Astronomer Royal pronounces to be the grandest problem in astronomy. It is solved by two different methods. One is by observations on the planet Mars in opposition, when it is, of course, nearest to the earth; or on the planet Venus when in conjunction, and also nearest to the earth. The other is by the transits of Venus across the sun's disc.

I have already stated that the *relative* distances of all the planets from the sun have been known, with considerable accuracy, since the time of Kepler. It only remains to find the *absolute* distance of one, and then, as the periodic times are known with great precision, Kepler's Third Law will furnish all the other distances.

The semi-diameter of the earth, seen from the sun, subtends an angle of a little more than $8\frac{1}{2}''$, ($8.''6$.) This is the sun's horizontal parallax. It reduces the earth, as seen from the sun, to less than one-half of the apparent diameter of Jupiter, as seen from the earth. To appreciate the delicacy of this problem, it must be borne in mind that an error of one second of arc in the parallax involves an error of about 12,000,000 of miles in the distance of the sun. Moreover, one second of arc is an extremely small quantity. None but the most perfect instruments can pretend to measure it directly. The $\frac{1}{1000}$ part of an inch, as any one will perceive, is an extremely small quantity to deal with. But a circle must have nearly 18 feet radius in order that $1''$ may occupy the space of $\frac{1}{1000}$ part of an inch. Kepler found reason to reduce the solar parallax from $3'$, as given by Ptolemy, to $49''$, which necessarily placed the sun at nearly four times the distance assigned by his great predecessor. And yet Kepler's measure was only one-sixth part of the true distance.

To settle this question, or at least with the hope of getting a nearer approximation, the French Academy, in 1672, sent Richer to Cayenne, in South America, to make observations on the parallax of Mars in opposition, while Cassini made contemporaneous observations at Paris. By computation based on these observations the sun's parallax was reduced to $9''.5$ as the probable value, which removed the sun to five times the distance adopted by Kepler.

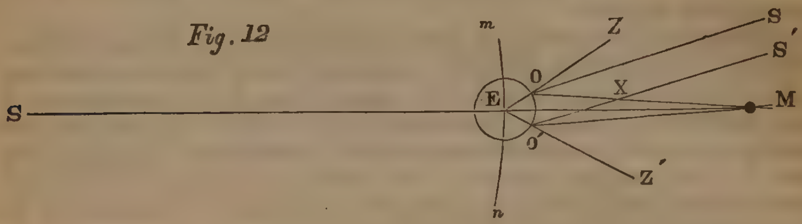
Flamsteed compared his own observations on Mars with those of Richer, and deduced $10''$. With the hope of obtaining still nearer results, Halley visited the island of St. Helena to observe the transit of the planet Mercury across the sun's disc in 1677, October 28, but the result was not satisfactory. He was inclined to adopt $15''$ as the true value.

The celebrated astronomical expedition of La Caille to the Cape of Good Hope, in 1750, had for one of its objects to [illegible]

planet Mars in opposition, contemporaneously with Cassini in Paris, Wargentin in Stockholm, and others in the north of Europe. These observations gave for the parallax of the sun 10″.4 nearly. The parallax of Mars was about 25″.

The method by which the results were obtained will be understood

Fig. 12



by a reference to figure 12. S on the left is the position of the sun, E the earth, M Mars in opposition. The stations of Wargentin at Stockholm and La Caille at the Cape of Good Hope were nearly on the same meridian. Let them be represented by O and O′, their latitudes being known. Then in the quadrilateral figure O E O′ M, the angle at E is known by the latitudes; the angles at O and O′ are known by the observed zenith distances Z O M and Z′ O′ M. These three angles would make known the angle at M. But to avoid the possible errors in determining the first three it is better to obtain M by direct observation. Its value will serve as a test of the correctness of the other angles. This angle at M is most accurately found by measuring the apparent distance, at each station, between Mars and some star near it which passes the meridian at nearly the same time. At O this distance would be S O M; at O′ it would be S′ O′ M. The angle at M is the difference between these two. For, on account of the great distance of the star, O S and O′ S′ are parallel; and therefore S O M = O X O′; but this latter being exterior to the triangle O′ X M, we have X M O′ = O X O′—X O′ M; hence the angle at M is equal to the difference between the observed distances of the star from Mars. The radii of the earth E O and E O′ being known, it is easy to compute the distance E M, the distance of Mars from the earth. It will now be very easy to find E S, the distance of the sun from the earth. From Kepler's Third Law we know that the *relative* distances of the earth and Mars from the sun are as 100: 152 nearly; that is, if the earth's distance were divided into 100 equal parts the distance from the sun to Mars would be 152 of those parts, and the distance from the earth to Mars in opposition would be 52 of the same parts. But the foregoing process gives us the absolute value of those 52 parts, and hence we can by a simple proportion find the value of the 100 parts between the earth and sun. Let m = the number of miles in E M; then to find the number in E S, we have 52 : 100 : : m : E S; or E S = $\frac{100m}{52}$

The observations of La Caille and Wargentin were made on the 6th of October, 1751. They gave for the parallax of Mars 24″.7, for that of [illegible] 10″.4, and for the distance of the sun a little more than

76,000,000 of miles. These results agreed pretty nearly with those derived from the observations of Richer, Cassini, and Flamsteed, three-quarters of a century earlier.

In 1760 Mayer, from analytical equations involved in the lunar theory, deduced a value for the sun's par. $= 7''.8$.

But the transit of Venus was now near at hand, which alone could satisfactorily solve this great problem. Dr. Halley was the first to perceive and urge the importance of the passage of Venus over the sun for this purpose. As early as 1716 he called the attention of astronomers to the two transits which were to occur in 1761 and 1769, and most earnestly urged them not to neglect so precious and so rare an opportunity of determining the planetary distances of the solar system. If these opportunities were neglected the like would not again occur for more than a century.

The transits of Venus invariably occur in June or December—those at the ascending node in June, at the descending, in December. The intervals between them are 8 years and 105½, then 8 and 121½, then 8 and 105½, and so on successively in that order.

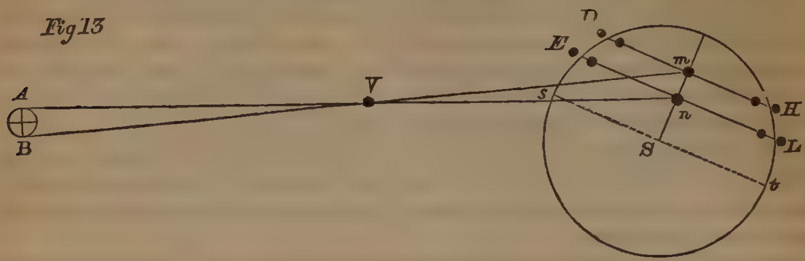
The transit of 1639, December 4, was observed by Horrox and Crabtree, two young men engaged in astronomical studies, in seclusion, as Grant says, in one of the northern counties of England. They, by good fortune, (for the time of the transit was not accurately known,) had "the privilege of witnessing a phenomenon which human eyes had never before beheld, and which no one was destined again to see till more than a hundred years had passed away."

In anticipation of the transit of June 6, 1761, encouraged by the earnest appeal of Dr. Halley, several European governments and learned academies sent scientific commissions to different parts of the earth to observe it. The English sent Dr. Maskelyne to St. Helena, Mason and Dixon to the Cape of Good Hope. The French Academy sent Pingré to the island of Rodrigues, in the Indian Ocean. The Russians sent Chappe to Tobolsk, in Siberia, and Rumouski to a station near Lake Baikal, on the Mongolian frontier. All the observatories in Europe were put in requisition.

I shall here explain the method by which the sun's parallax is determined by the transit of Venus. At different stations on the earth the planet will be seen to traverse the sun's disc in different lines, and will occupy unequal times. As the relative motions of Venus and the sun are accurately known, the duration of the transit will show the particular chord along which it passed. The two chords, as seen by two observers favorably situated, being known, will make known the perpendicular distance between them. This perpendicular distance is then compared with the diameter of the earth or some known part of that diameter, and at once gives the sun's parallax. The peculiar advantage of this method is, that the distance between the two apparent chords traversed by the planet is more accurately known by the difference of times than by any direct micrometrical measurement. This process will be easily understood by reference to fig. 13, where A B represents the earth, V Venus, and S the sun. For the most successful result, the stations A and B should be at the extremities of a diameter perpendicular to the plane of the ecliptic. At A Venus will be seen to traverse the chord E *n* L, at B the chord D *m* H.

Now, by observing the instant of the several contacts of the limb of Venus with that of the sun, the exact time in which the centre of the planet traverses the chord will be known. The mean diameter of the sun is 32′ 3″ nearly, or 1,923″. By the known angular velocities of

Fig 13



the two bodies the time of traversing the diameter becomes known. Calling t the computed time of traversing the diameter, t' the observed time of traversing the chord, we shall find the number of seconds in the chord by the proportion $t : t' :: 1{,}923''$: the number of seconds in the chord. By drawing radii from S to E and D we readily find S n and S m from the right-angled triangles S n E and S m D, and hence $n\ m$ the perpendicular distance between the chords; that is, we shall know the number of seconds subtended by the line $m\ n$, as seen from the earth. We can also compare $m\ n$ with A B, they being parallel lines in the same plane perpendicular to the plane of the ecliptic. Seen from V, these lines subtend the same angle. Their relative lengths must, therefore, be as their distances. But it is known that $v\ n : v$ A :: 72 : 28 nearly; hence, we have 72 : 28 :: $m\ n$: A B. But we have determined the number of seconds subtended by $m\ n$ as seen from the earth; this proportion, then, gives the number of seconds subtended by A B, seen at the same distance; that is, as seen from the sun. We then have the angular diameter of the earth as seen from the sun. One-half of this is the long-sought element in astronomy, the sun's horizontal parallax. On account of the great importance of this process, and the great interest which always attaches to the transit of this planet, I have ventured to give the details which are necessary to appreciate the grounds upon which the result rests. It is proper to remark, before leaving this point, that the two stations A and B cannot well be at the extremities of a diameter, nor will it often happen that the right line joining them will be perpendicular to the plane of the ecliptic. But, what comes substantially to the same thing, the line joining the stations will always be known, and can easily be reduced to an equivalent perpendicular one, so that the accuracy of the final result will scarcely be impaired by this circumstance.

The only observation of that transit made on the American continent, so far as I am aware, was by Professor John Winthrop, of Harvard University. The transit came on early on the morning of June 6. For the purpose of a favorable station Mr. Winthrop repaired to St. John's, in New Brunswick. His observations were com-

municated to Mr. James Short, of London, and, with others, were published in the transactions of the Royal Society for 1764. From the discussion of seventeen observations made at different places Mr. Short found the parallax to be 8″.6.

The same observations were discussed by Mr. Thomas Hornsby, professor of astronomy at Oxford. His result is 9.″7, more than 1″ greater than Short's. Pingrè's computations gave 10″.1. Rumouski, 8″.3. On account of such large discrepancies these results were not very satisfactory.

But another transit was to occur June 3, 1769; and renewed and more extended preparations were made to secure the best possible observations. Scientific societies and enlightened governments united their efforts to establish stations in distant parts of the earth most favorable for observation.

Besides the observations of Dr. Maskelyne at the Greenwich observatory, and many others in England, the Royal Society, with the aid of the government, sent out the famous expedition of Capt. Cook to the South Seas, where the transit was observed by Mr. Green, the astronomer, by Captain Cook, and Dr. Solander, the botanist of the expedition.

Another commission, consisting of Messrs. Wales and Dymond, was sent to Hudson's Bay; while Mason and Dixon, who had observed the transit of 1761 at the Cape of Good Hope, observed this in Ireland. And still another, under the direction of Mr. Call, was sent to Madras.

The French Academy sent Pingré to St. Domingo, and the Abbe Chappe to California, both of whom had observed the preceding transit, the former in the Indian ocean, the latter in Siberia. Chappe made his observation at the village of St. Joseph, in California, and, lingering a short time to complete some observations for the longitude of the place, was seized with an epidemic and died on the 1st of August following. His observations were preserved and sent to Paris by one of his assistants.

The Academy of St. Petersburg took the most enlightened interest in the event, and sent astronomers to three different stations in Lapland, to one on the banks of the Lena, to another on the shores of the Caspian, and to several places in the interior of Asia.

The King of Denmark sent Father Hell, professor of astronomy in Vienna, to Wardhus, at the northern extremity of Norway. Lanman went to Cajanebourg, in Finland.

In this country the American Philosophical Society of Philadelphia, under the lead of Dr. Rittenhouse, took the most active and conspicuous part in this enterprise, which united the astronomical labors of all countries. As the time for preparation drew near the society appointed commissions to make observations in the three separate places: one at Norriston, (now Norristown,) the residence of Rittenhouse, seventeen miles northwest of Philadelphia; one in Philadelphia, and one near Cape Henlopen. Dr. Rittenhouse had the principal charge of the first station, Dr. Ewing of the second, and Mr. Biddle of the third. The liveliest interest was felt in the subject. The day was remarkably fine, and the observers were able to get excellent observations.

This transit was also observed by Professor Winthrop, of Cambridge, who had observed the previous transit in New Brunswick, and by Dr. West of Providence. Observations were also made by the Earl of Stirling, at Baskenridge, in New Jersey, and by Captain Holland near Quebec.

Several valuable papers, devoted to the record and discussion of these observations, will be found in the transactions of the American Philosophical Society for 1769, and many in the transactions of the Royal Society of London for 1769 and 1770.

Professor Hornsby, of Oxford, who had computed the sun's parallax from the observations of 1761, computed the same from five or six of the best observations of 1769. But the most complete discussion of the subject was by Lalande, who, by the close of the year 1769, had collected a great number of observations, and discussed them in the most elaborate manner. His results were published in the Gazette of France, in January, 1770.

In consequence of the unfavorable state of the weather only two of the northern stations furnished full and complete observations, viz: Wardhus and Cajanebourg. And, unfortunately, there was strong reason to suspect that those at Wardhus, by Father Hell, were not genuine. There was a delay and a reluctance in giving them to the public, which much required explanation. And, after the fullest investigation, there was reason to believe that some of them, at least, were interpolations.

The close agreements of the computed results of observations, most widely separated, taken two and two, gave assurance of a close approximation to the truth. The following were obtained by Lalande:

California and Hudson Bay	8″.56
Hudson Bay and Otaheite	8″.55
California and Otaheite	8″.53
Wardhus, Cajanebourg, and Otaheite	8″.62

The result of an immense amount of calculation by himself, Lexell, Euber, Pingré, and Durèjour, gave, 8″.5; 8″.7; 8″.8. In England, Hornsby found 8″.8, Maskelyne 8″.7, Smith 8″.6. As a mean of all the results, 8″.6 was adopted, which is the same as Short obtains from the observations of 1761. The importance of arriving at the nearest tenth of a second will be seen by considering that *one-tenth* of a second in parallax corresponds to about 1,000,000 miles in the sun's distance.

"Such," says Lalande, in closing his history of this astronomical event, "such is the result of this celebrated transit of Venus, which has occasioned so many voyages and so many volumes, and which has taught us, much better than we knew before, the extent of our universe, or at least of our solar system. This transit may be regarded as one of the memorable epochs of the astronomy of the eighteenth century."

But succeeding astronomers were far from being content to adopt, without further inquiry, the foregoing conclusion.

Encke, the eminent veteran astronomer of Berlin, has re-examined and most elaborately collated and discussed all the observations made at both the transits of 1761 and 1769, and given to the public the results in two volumes, published, the one in 1822, the other in 1824.

From the transit of 1761 he finds $P = 8''.53$
From the transit of 1769 he finds $P = 8''.60$

Mean $P = 8''.57$

The sun's distance is therefore very nearly 95,300,000 miles. From this all the other planetary distances are easily obtained by Kepler's Third Law. Airy, in his Lectures on Astronomy, puts the distance at 95,500,000, with a probable error of not more than 500,000 miles.

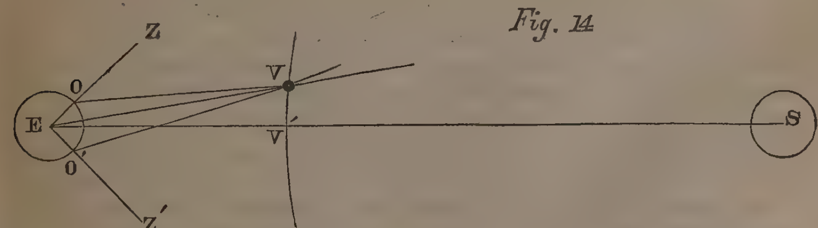
It is worthy of remark, as showing that all true methods are in harmony with each other, that Professor Burg, in 1824, following the footsteps of Mayer, deduced the solar parallax from analytical investigations of the Lunar Theory, and found for a result $8''.62$, very nearly coincident with that of Encke. Laplace had obtained, in the same way, $8''.61$, a result almost identical with that of Burg.

These remarkable coincidences of analysis with observation in the remote and untrodden fields of science furnish, as Laplace suggests, one of the most striking proofs of universal gravitation.

Before bringing these remarks to a close, I must call your attention to one other effort to approximate still nearer to this fundamental element in the solar system, an effort recommended by the ablest astronomers, at home and abroad, and deemed worthy of the combined labor of different countries. I refer to the United States naval astronomical expedition to the southern hemisphere during the years 1849, 1850, 1851, and 1852, under Lieutenant J. M. Gilliss.

In 1847 Dr. Gerling, a distinguished astronomer and mathematician of Marburg, in Germany, called the attention of astronomers to the importance of repeating the observation on Mars in opposition, and especially of making observations on Venus during the inferior conjunction, for the more exact determination of the sun's parallax. He suggested reasons for believing that, with the increased power and accuracy of instruments, together with the delicate and refined methods of observation now in use, most valuable results, additional to any hitherto realized, might be obtained. He particularly urged the importance of observations on Venus, which had not heretofore been rendered available for this purpose. The principle of this will be understood by reference to figure 14.

Fig. 14.



Two observers at O and O′, by observation obtain the angle at Venus, viz: O V O′, in the same manner as before given in the case of Mars, from which the distance E V can be computed. The planet

being within two or three degrees of the sun, this distance will differ but little from E V′. The horizontal parallax of Venus will then be readily found.

But the parallax of Venus and the sun will be inversely as their distances. By Kepler's Third Law we should have—

$$\begin{aligned} SE : SV' &:: 51\tfrac{1}{2} : 37 \text{ nearly.} \\ \text{Whence } SE : V'E &:: 51\tfrac{1}{2} : 14\tfrac{1}{2} \\ \text{or } 51\tfrac{1}{2} : 14\tfrac{1}{2} &:: \text{Par. Venus} : \text{Par. Sun.} \end{aligned}$$

In this proportion the terms are all known except the last, and hence we have the sun's parallax.

The letter of Dr. Gerling to Lieutenant Gilliss was in anticipation of the publication of his views in Germany. Lieutenant Gilliss promptly brought the subject to the notice of our ablest astronomers, and, with their hearty concurrence, enlisted Congress, the government and the Smithsonian Institution in the enterprise.

The manner in which the expedition was undertaken and carried out reflects the highest credit upon the ability and untiring energy of Lieutenant Gilliss. The very moderate appropriation of $5,000 was authorized by Congress to enable the Secretary of the Navy to defray the expenses of the expedition. Furnished with instruments fitted expressly for the expedition, viz: two telescopes, a larger and smaller, equatorially mounted; a meridian circle, of large size and exquisite finish; clock and chronometers; and two assistants, Messrs. MacRae and Hunter, Lieutenant Gilliss, by order of the Secretary of the Navy, repaired to Santiago de Chile, and erected his observatory so as to commence observations in December of 1849, which were continued till September of 1852. By previous arrangement, simultaneous observations on both Venus and Mars were to be made at the Washington observatory, under the direction of Lieutenant Maury. It was expected also that other observers, both in this country and Europe, would, as far as possible, co-operate in a work in which all astronomers were alike interested.

On the return of the expedition the vast mass of observations were placed in the hands of Dr. B. A. Gould, jr., for reduction and discussion. The well known ability of Dr. Gould gave assurance that nothing would be wanting to insure the most accurate results. The laborious undertaking has been accomplished, and the result published in the third volume of the Naval Astronomical Expedition. The parallax thus obtained from purely American observations, and by a method entirely new, at least so far as the observations on Venus are concerned, agrees very nearly with those obtained by the transit of Venus, viz: 8″.5. If we cannot say that our own astronomers have attained a closer approximation to the truth than had before been reached, which could hardly be expected, we can say that by a new and independent method they have added a most valuable confirmation to results before obtained. It is not too much to say that this enterprise, in its conception and consummation, reflects honor upon the scientific character of our country, and will be highly appreciated wherever astronomical science is cultivated.

The next two transits of Venus will be on December 8, 1874, and

December 6, 1882. It may be expected that American astronomers will take an important part in the observation of these transits.

Of these two transits, that of 1882 will be the more favorable to an exact determination. In a very interesting paper communicated to the Royal Astronomical Society of London, in May, 1857, the astronomer points out the special advantages which the United States will possess for making accurate observations.

In the first place, the two regions of country most favorable for observation are the United States and a portion of the Antarctic land discovered by Captain Wilkes, of the United States navy. In the second place, we have a large number of observatories situated at such convenient distances that any local cloudiness which might prevent observations at some stations would not affect others. In the third place, we have the great and peculiar advantage of an extended system of magnetic telegraphs by which the clocks and chronometers of all the stations might easily be connected so that all the observations might be made by one clock, say that of Washington.

Humanly speaking, therefore, he remarks, we may say that the probabilities for the accurate and efficient observation of these phenomena in the United States are vastly superior to any that could have been reckoned on in any former time, or to any that could now be anticipated in any other region.

SIDEREAL ASTRONOMY.

In my last lecture I discussed the methods of determining planetary distances, first by finding the sun's distance from the earth, and then, by means of Kepler's Third Law, computing the distances of the other planets. The distance of the sun I stated to be 95,300,000 miles, with a probable error of not more than half a million of miles. This proportional error, and no more, will run through all the measures of planetary distances. In this respect all has been done, or nearly all, that can be done before the next transits of Venus in 1874, December 8, and 1882, December 6.

I shall, this evening, invite your attention to the subject of *Sidereal Astronomy*. A glorious and an inspiring sight it is to look at the starry heavens. So vast, so brilliant, so pure, they seem to raise the soul to diviner contemplations than any scene which pertains to earth. The first impression on looking at the heavens is, that the stars are absolutely innumerable, but on a more careful consideration we become satisfied that this first impression is erroneous. If the attempt is actually made to number them, it will be found that not more than about 3,000 can be seen at any one time by the naked eye. The whole number thus visible in the heavens does not probably exceed 6,000 or 7,000.

Very early in the history of astronomy the stars were distributed into groups called *constellations*, to which particular names were given, depending upon some fancied resemblance between the configuration of the stars and the form of the object or animal from which the name was taken. Thus we have the constellation of the Great Bear, the Little Bear, the Eagle, the Swan, the Lyre, &c. These constellations

are convenient in reference to a general description of the heavens. The more conspicuous stars have individual names as Sirius, Procyon, Regulus, *&c.*

The principal classification of stars, however, is in reference to their *magnitudes*. But we must here bear in mind that the stars have no assignable area or size. They have no measurable disc, like the planetary bodies. The stars of the first magnitude, when viewed with a good telescope under favorable atmospheric circumstances, sharpen down to a mere brilliant point. The classification is really based on *brightness;* and stars of the first magnitude are simply the *brightest* stars. Any one on looking at the heavens on a clear, moonless night, will be able to distinguish many degrees of brightness between Sirius, the brightest star in the heavens, and one that is barely visible to the naked eye. It would not be difficult, perhaps, to select twenty stars within these limits, which twenty different persons, without any concert, would arrange in the same order. And this only shows how quickly and how truly the eye discriminates slight shades of difference in brightness. Astronomers have, however, divided the stars visible to the naked eye into six classes, and the telescopic stars into ten additional ones, making sixteen in all. Stars of the 15th and 16th classes are test objects for the best telescopes which have been made. It must not, however, be supposed that there is any very well defined difference between the faintest star of the first magnitude and the brightest of the second. These will not differ more from each other than several of the stars of either class.

While it is very easy to arrange the stars in the order of their brightness, it is not easy to determine *how much* they differ the one from the other. Many attempts have been made to ascertain *photometrically*, (that is, by measuring in some way the quantity or intensity of light,) *how much* the light of Sirius, for instance, exceeds that of Aldebaran, or any medium star of the first magnitude. These efforts have extended to the comparison of a star of the 6th magnitude with Sirius, and, again, Sirius with the moon and the sun. Researches upon this subject are attended with many difficulties, and the results cannot, of course, be considered very exact, and yet they afford tolerable approximations to the truth. From comparisons which have been made by different methods and by different persons, it is concluded that the light of Sirius is fully equal to three times that of a star of medium first class magnitude; in other words, three first class stars of the brightness of Aldebaran or Regulus, united, would only make one of Sirius. The comparison being restricted to medium stars of their respective classes, one of the first class is equal to four of the second, eight of the third, and one hundred of the sixth.

Astronomers have agreed to place in the first class not more than 23 or 24 of the brightest stars; in the second, 50 or 60; in the third, about 300. Beyond the third class the numbers increase with great rapidity. The whole number which have been accurately catalogued, down to the seventh class inclusive, is about 15,000. Descending to the telescopic classes, the numbers have become immensely great. Struvè, whose researches have been specially directed to this branch of astronomy, concludes that the number of stars situated in Bessel's

zone, extending 15° on each side of the equator, which were visible in Herschel's 20-foot reflector, amounted to more than 5,800,000. But this zone covers only about one-quarter of the heavens, and is by no means that portion which is the richest in telescopic stars. The great belt known as the Milky Way presents vast regions where the minute stars are incomparably more dense than in Bessel's zone. To say, then, that the whole number of stars visible in the telescope amounts to many millions, is but an imperfect and inadequate statement of the fact. We might still say, the half is not told us. But, then, turn away from the contemplation of single, scattered stars, and look at the close clusters, of which there are so many in the heavens, where many thousands of minute stars are so densely crowded together that the very best powers of the telescope are required to separate them. If they were thrown together, a million of visible stars would scarcely occupy so large a space in the heavens as the sun's disc. Then, from these stars, which are separately and distinctly visible, look again at the "star dust," as Herschel calls it, which gives a general illumination to the Milky Way, and is visible only in the aggregate, and which yet dimly shadows forth the existence of individual orbs more numerous than all that are seen. Who, then, shall count the stars, or tell the number thereof? Down to this time more than 100,000 have been accurately catalogued. Lalande's Catalogue, republished by the British Association, in 1837, alone contains 47,390.

Sidereal astronomy presents many points of interest. It may be asked, what the stars are, and where they are, and whether they are unchangeably the same? Are they subjected to any law of motion? Is there any bond of union between them? Do they tell us anything of time and space, of creative power and infinite intelligence, that we should not have known without them? To some of these questions we shall advert this evening. Others of them belong to after ages in the world's history.

Following out the plan which I have proposed to myself in these lectures, I shall first endeavor to show how we arrive at some estimate of the distances of the stars. I have, in the previous lecture, explained the method of finding the dimensions of the solar system, in miles. The distance of the nearest fixed star is so vast that we shall best express it in terms of the velocity of light. But if I tell you that light moves at the rate of 192,000 miles in a single second of time, you will very naturally ask me how this can be known. So extraordinary a statement certainly ought not to be credited but upon good and sufficient grounds. This problem is one of so much interest in itself, and so needful to our progress, that I shall venture to give a few moments to its illustration before proceeding to discuss the distances of the stars.

The velocity of light is known by three separate means: 1. By the eclipses of Jupiter's satellites. 2. By the aberration of light. 3. By direct experiment.

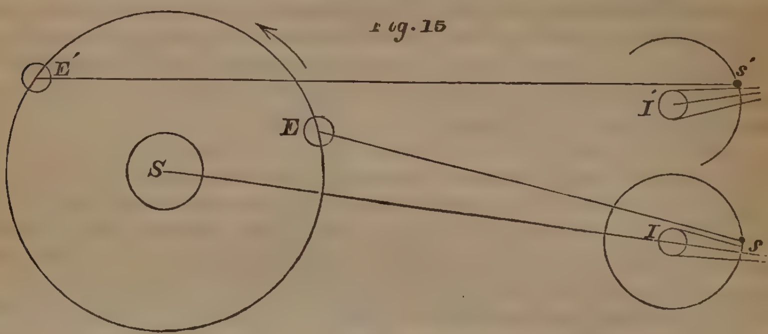
Immediately on the discovery of the telescope by Galileo, in 1610, his attention was drawn to the satellites of Jupiter, then for the first time seen. They revolve round the primary in periods of from less than two to more than sixteen days. Their periodic times were soon

determined with considerable precision. But it was also found that they presented remarkable inequalities. When the earth in her orbit was receding from Jupiter, the periodic times were too long. On the contrary, when she was approaching him they were too short. These discrepancies were the occasion of much perplexity.

Arago, in his popular astronomy, gives to Lord Bacon the credit of having first suggested that the inequalities might be due to the fact that *time* was occupied in the transmission of light; that the effect of light was not, as had been supposed, simultaneous at all distances.

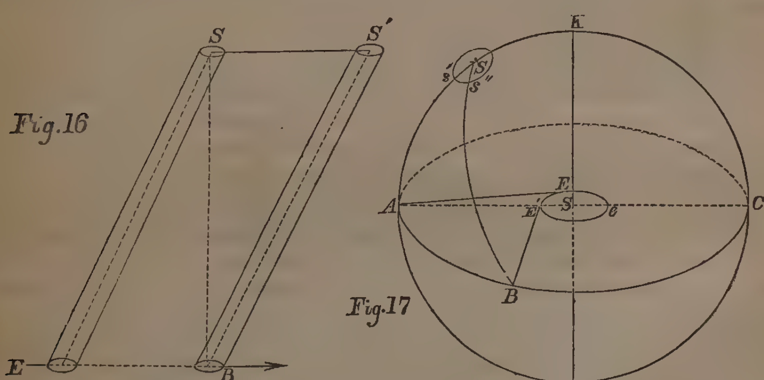
Roemer, an eminent Danish astronomer, was the first to urge this fact as necessary in order to account for the apparent irregularities. Researches upon these satellites occupied the attention of eminent astronomers for more than half a century. And it was not until after the lapse of more than a hundred years from the time of their discovery that their motions were fully explained; and no explanation was sufficient which did not involve the "equation of light." The subject will be easily understood by reference to fig. 15.

Fig. 15



Let S be the sun, E E′ the orbit of the earth, I I′ a portion of the orbit of Jupiter, *s* and *s*′ the orbit of one of the satellites. The primary casts a shadow behind it in a direction opposite to the sun, by which the satellites are often eclipsed. In some portions of the earth the *immersion* and the *emersion* of the satellites can both be seen; in other positions only one of them. When the earth is at E and Jupiter at I, the emersion of the satellite is seen at *s*. When the earth has advanced in her orbit to E′ and Jupiter to I′, the emersion will be seen at *s*′. While the earth is passing along the side of her orbit approaching the planet the immersions are seen. While she is moving from the point of her orbit nearest to the planet the intervals between the eclipse are too long; and while returning from the most remote to the nearest they are too short. And this difference, in the course of a complete synodic revolution, amounted to more than 16½ minutes. It was at length found, by accurate calculation, that light occupied 16 m. 36 sec. in traversing the diameter of the earth's orbit, or eight minutes and eighteen seconds in coming from the sun to us. With this allowance, the discrepancies between the computed and observed times of the eclipse entirely disappeared. This result fixed the velocity of light at about 192,000 miles per second.

But the foregoing result was not, perhaps, fully concurred in by astronomers till Dr. Bradley, in 1725, discovered the *aberration of light*, one of the most beautiful discoveries in the whole history of science. Dr. Bradley, while prosecuting researches for the purpose of detecting, if possible, the annual parallax of the stars, found that all the stars were subject to an annual change of position, and that they described orbits about their mean places having 40″ of arc for their major axis. Those situated in the ecliptic moved backward and forward in a straight line. In proportion as they are removed from the ecliptic the minor axes of the orbits increased, while the major axes of all remain the same. And, what is quite singular, they are all displaced or projected forward in the direction of that point in the heavens towards which the earth is at the moment moving. The true explanation of this fact was far from being obvious. It was at length suggested to Dr. Bradley, on an occasion of being rowed across the Thames. He observed that the streamer, at the top of the mast, indicated a change in the direction of the wind while the boat was getting under way. He inquired of the boatmen what made the wind change when the boat began to move? They could give no explanation, but said they had often observed it. But, on reflecting upon the subject, Dr. Bradley explained it on the principle of the parallelogram of forces. The streamer would necessarily take the direction of the diagonal of a parallelogram which should have for one side the velocity of the wind, and for the other the velocity of the boat. This at once explained, also, the displacement of the star. It must appear in the direction of the diagonal of a parallelogram which should have for one side the velocity of the earth, and for the other the velocity of light.



In figure 16, if E B represents that portion of the earth's orbit which is described in one second of time, and E S the distance traversed by light in one second of time, then the star which is really at S will appear to be at S′, determined by the parallelogram formed on E B and E S as sides. The angle S B S′, which measures the displacement, is called the aberration, and when largest is always equal to 20″ of arc. With every star this maximum occurs twice in the year, at the time when the line of direction of the earth makes a right

angle with the visual ray from the star. In the triangle E B S′ the angle S′ E B, very nearly equal to S E B, is always known from the position of the star, the angle E S′ B = S E S′ is known by observation, E B = velocity of the earth, B S′ = E S = velocity of light; we then have sin. E S′ B : sin. S′ E B : : E B : B S′. But twice in the year E S′ B = 20″ and S′ E B = 90°, we then have—

$$\sin. 20'' : R :: \text{vel. of earth} : \text{vel. of light};$$

or, converting the R = sin. 90° in seconds and leaving off the sines, we have—

$$20'' : 206265'' :: \text{vel. of earth} : \text{vel. of light}.$$

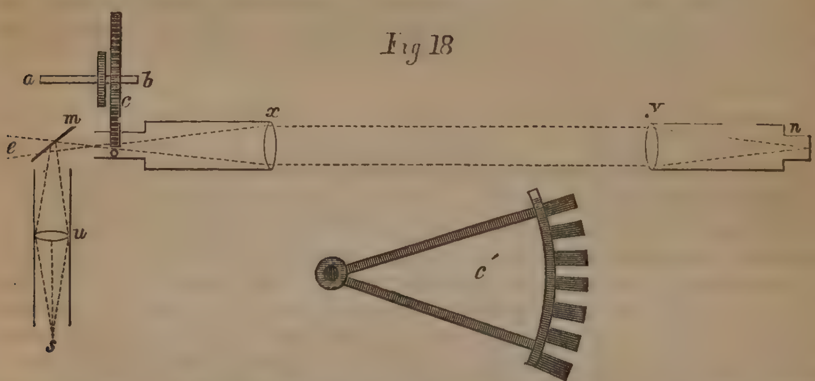
Whence the velocity of light $= \frac{206265 \times \text{vel. of earth.}}{20}$

If we introduce into this equation the velocity of the earth, which is nearly nineteen miles per second, we shall obtain a result very nearly equal to 192,000, as given by the eclipses of Jupiter's satellites.

The effect of aberration for the entire year will be seen by figure 17, where E E′ E″, &c., is the earth's orbit, S the mean place of a star, and S′ S″ S‴, &c., the apparent orbit described by the star, or the ellipse of aberration.

There is a third determination derived from direct experiment, which is too important to be omitted in this connexion. In 1849, M. Fizeau, of Paris, constructed a most ingenious apparatus, which had the requisite delicacy for so difficult an experiment. The outline of it is given in figure 18.

Fig 18



s is a lamp, *u* a lens placed in a tube which serves to converge a beam of light on *m*, a plane unsilvered glass, placed in a tube; the glass *m* reflects the convergent beam of light to a focus at *o*. *x* is a lens which receives the light and refracts it into a parrallel beam *x y*; at *y* is another lens, which converges it to a focus on the plane mirror *n*, from which it is reflected directly back, passes again through the lens *y*, thence through the lens *x*, thence through the unsilvered glass *m*, and reaches the eye at *e*. At the point *o*, where the light is brought to a focus, an opening is made in the tube in which the toothed wheel *c* is made to revolve with great velocity by mechanism not here represented. There is also a diaphragm placed across the tube,

directly behind the wheel, with a rectangular opening in it. The form of the opening in the diaphragm and in the teeth of the wheel are seen enlarged in a part of the wheel c^1, figure 18. As the wheel c revolves, the opening in the diaphragm is successively opened and closed with great rapidity. If it were to be permanently open, then the light from the lamp would fall upon the plane glass m, a portion would be transmitted and a portion reflected, which latter portion would pass through the lenses x and y, be reflected at n, return again, fall a second time upon m, and be transmitted to the eye at e. In this state of the apparatus the eye sees a bright point at the focus o. The bright point continues visible until the velocity of the wheel c is such that one of its teeth passes over the notch in the diaphragm and thus prevents the reflected light from coming to the eye. The bright point is then eclipsed. This will necessarily take place whenever the time occupied by the tooth in passing the space of the notch is the same as that required by light in going from o to n and returning.

When the velocity of the wheel becomes so great as to close and open the notch again while the light is going and coming, the bright point will reappear. As the rotary speed of the wheel increases, the point will be successively eclipsed. The rotary velocity of the wheel is registered by appropriate mechanism so as to mark with precision the number of turns to a second, while the number of teeth in the wheel will serve to determine the time in which one tooth passes the notch. The distance between the stations was 8,633 metres, equal to five and one-eighth miles nearly. The apparatus indicated the time of traversing the double distance, or ten and two-third miles, to be about $\frac{1}{15000}$ or $\frac{1}{16000}$ of a second, which makes the velocity of light very nearly the same as that given by the preceding methods. Physical science presents few more striking results than this of M. Fizeau.

From the near agreement of these three independent methods of determining the velocity of light we may safely conclude that the probable error is small. Light moves with the amazing velocity of 192,000 miles per second.

We shall now proceed to inquire into the distance of the fixed stars. And we may state, in the outset, that the only means of arriving at an indication of this is an *annual change* in the position of the star. But there are certain changes which are dependent upon known causes which must first be allowed for. These are refraction, aberration, and nutation. The refraction varies with the altitude of the star; aberration for any particular star depends on the season of the year; nutation, (another fine discovery of Dr. Bradley, in consequence of which the star describes a little ellipse about its mean place once in about nineteen years,) depends upon the position of the nodes of the moon's orbit. This inequality is due to the action of the moon upon the spheroidal figure of the earth. The amount of these corrections is well known. Now, if there is any change in the position of a star over and above what is due to the above causes it must be referred either to its own proper motion or to the change of position of the earth in its orbit. But these two are not liable to be confounded the one with each other. The *proper motion* will be progressive from year to year in the same direction. Any change due to the motion of the

earth will necessarily be periodic and the star must return to the same place at the expiration of a year. A proper motion has been detected in many of the stars, amounting in some to 4″ or 5″ in a year.

Any change due to the motion of the earth is called the *annual parallax.* The only means within the reach of astronomy of finding the distance is by means of this parallax.

An obvious proof that the stars are immensely distant is that, except under the severest possible scrutiny, they appear to hold the same relative places at all seasons of the year. Our change of position, involving a distance of nearly 200,000,000 of miles, dwindles down to nothing in comparison with the line which extends from the earth to the star.

In figure 19, let S be the sun, A E B the earth's orbit, and *s* a

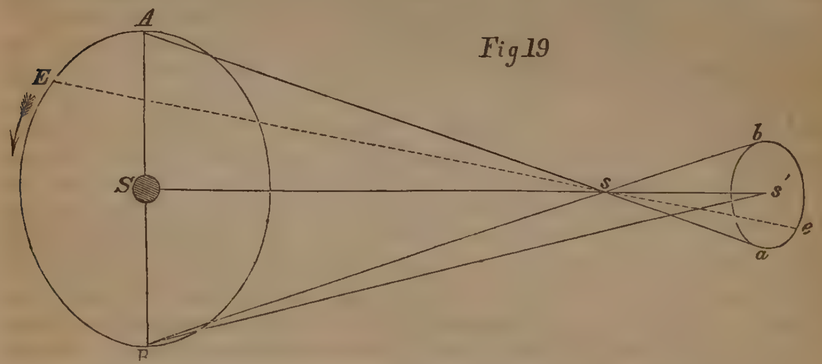


Fig 19

star; then the angle A *s* S, or the angle subtended by the radius of the earth's orbit, as seen from the star, would be the annual parallax of the star. If this angle were so much as 1″, it would follow that the distance of the star must be 206,265 times the distance of the sun. In that case light would require more than 3½ years in coming from the star to us. But in no case is the parallax of a star so large as 1″. As Biot has remarked, "an angle so large as 1″ could not have escaped universal recognition." What we are now entitled to say then is, that *light from the nearest fixed star would require at least more than* 3½ *years to reach our earth.*

There is no presumption that the stars are all equally distant. On the contrary there is every probability that their distances are very unequal, and hence that some stars of the first order of intrinsic splendor appear faint from their vast distance. Huyghens, assuming that Sirius was equal in intrinsic brightness to our sun, concluded from a computation based upon the well known law that the intensity of light diminishes inversely as the square of the distance, that Sirius must be 28,000 times more distant than the sun; in other words that our sun at that distance would appear no brighter than Sirius does now. But this estimate of the distance, as we now know, is far too small. At only that distance the parallax would be four times as great as that of the nearest known star. Dr. Wollaston, by very ingenious photo-

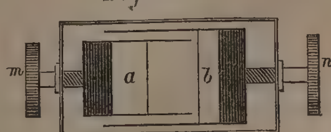
metric measurements, concluded that Sirius must be 140,000 times more distant than the sun. But even this is much within the true distance.

But let us glance at the actual measurements which have enabled the astronomer, in some few cases at least, to sound the amazing depths of the heavens.

The star γ Draconis, of Flamsteed's catalogue, has a very large proper motion, amounting to nearly 5″ annually. Under the supposition that those stars which have the greatest proper motion are nearest to us, and therefore most favorable to researches on the parallax, this star was selected by Dr. Bradley for special observations, with a view to detect this element. It had also the great advantage of passing near the zenith of the Wansted observatory, by which the troublesome irregularities of refraction would be avoided. He failed to detect any parallax, but his labor was rewarded by the beautiful discovery of the aberration of light. Bradley depended upon finding a variation in the elements of right ascension and declination. But this is by no means the most delicate test which can be applied for the determination of a minute annual change in the position of the star.

Galileo was the first to suggest that where a large and a small star are very close together the smaller star might appear faint from being placed at a vastly greater distance than the larger. If this were not always the case, of which there is no probability, it would be likely to occur in some instances. Wherever this holds good the stars will undergo an annual change in their relative positions, either approaching and receding from each other, or the one revolving about the other. Thus, in figure 19, if we suppose *s* and *s*′ to be two stars situated in a right line from the sun and in the direction of the pole of the ecliptic, as the earth goes round in her orbit A E B the star *s* may appear to revolve round *s*′, and it must do so if the radius of the earth's orbit holds any assignable ratio to the distance of the nearer star. Thus, when the earth is at A, *s* will appear at *a* in the distant heavens; when the earth is at E the star will appear at *e;* the earth at B will carry the star to *b;* and hence while the earth goes round in the orbit A E B the star S will appear to go round *s*′ in the curve *a e b*. No instance has been discovered where this idea has been fully realized. Nor indeed could any available results be obtained from it until a very late period, for the want of instruments fitted to measure so small an angle as the largest annual parallax. The micrometer in its different forms supplies this want. The manner in which very minute angles are measured by this appendage to the telescope will be understood by a reference to figure 22, which is a rectangular frame with a fine screw at each end passing through the frame and attached to sliding pieces within it. These sliding pieces carry the spider lines *a* and *b*, which by turning the screws are made to approach or separate from each other. Graduated circles are fixed to the heads of the screws. Suppose one complete revolution of the screw changes the position of the spider lines by 2′ or

Fig 22



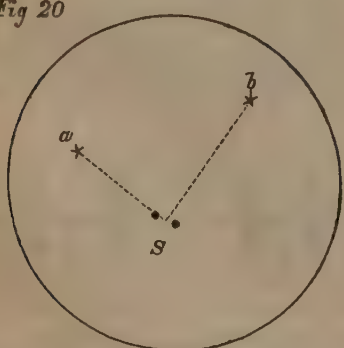
120″, and let the circles be divided into 360 parts, then one division on the circle will correspond to one-third of a second between the spider lines. This apparatus, called the *micrometer*, is placed in or across the tube of the telescope near the eye piece. It is sometimes furnished with a slip of metal just below the spider lines, which marks the interval in seconds between them. The distance between two stars or the diameter of a planet is measured by adjusting the instrument so that the stars shall be bisected by the lines, or the disk of the planet will lie exactly between them. The turns and divisions of the screw which bring the lines together will give the angular distance sought in this case to the one-third of a second. Large telescopes fitted with micrometers are indispensable to researches upon the distances of the fixed stars. The value of one turn of the screw is fixed by directing the telescope to two well defined objects of a known angular distance apart.

Special researches upon this branch of astronomy have been made by Struvè, Bessel, Peters, Henderson, Maclean and Groombridge.

In 1835 Struvè, then of Dorpat, now of the Great Russian Observatory at Pulkowa, near St. Petersburg, commenced a series of observations on the bright star in the Lyre. This star has a very minute companion at the distance of 43″. Struvè was able to detect an annual variation in this distance, from which he deduced the annual parallax of α Lyræ to be 0″.261, from which it follows that light would be about fourteen years coming from that brilliant star to us. The light which it sheds upon us to-night started on its career fourteen years ago.

But the researches of Bessel in connexion with the star 61 Cygni, form an important epoch in the history of stellar astronomy. He was furnished with a magnificent heliometer, made by Frauenhofer, with a micrometer of the greatest delicacy. He brought to the research an array of instrumental means which no previous astronomer had been able to command. His consummate skill as an observer, in connexion with the exquisite instruments in his hand, enabled him to furnish results which have commanded universal confidence. His observations were commenced at Königsberg in 1835, and continued to 1840. His field of view is presented in figure 20, where S is the double star 61, *a* and *b* are two minute stars, situated nearly at right angles from S, the former at the distance of 7′, the latter at 11′; the middle of the two stars S was the point from which the distances of *a* and *b* were measured. From the configuration of the stars, if S approached *a*, it would, three months later, approach *b*; at the expiration of another three months it would have receded from *a*, and then after the same interval, from *b*. This, in fact, was the order of change which was observed.

Fig 20



In other words, S revolved in a little orbit about its mean place. In

the discussion of his observations, on which, as Herschel remarks, "every imaginable cause of disturbance was taken into careful consideration and its effects rigorously calculated," he reached the conclusion that the parallax of 61 Cygni was 0″.348.

From this we infer that light would reach us from this star in $9\frac{1}{4}$ years. This result of Bessel has received the most ample confirmation by Peters of Pulkowa, who, in a series of observations, made in 1842 and 1843, with consummate address in the use of every refinement which could insure accuracy, found the parallax of this same star to be 0″.349, differing from the result of Bessel by only the $\frac{1}{1000}$ of a second. Such a coincidence between the results of different observers, with different instruments and in different places, cannot but inspire great confidence in the conclusion to which they have come.

The star *α* Centauri, the brightest star in the southern constellation, has been much observed with a view to its parallax; first by Henderson in 1832 and 1833, then by Maclean in 1839 and 1840, and again in 1848, both at the Cape of Good Hope. The mean of the results gives for the parallax of this star 0″.915, which places it nearer to our system than any star whose parallax has been determined. And yet light would be nearly four years in coming from this our nearest stellar neighbor.

The parallaxes of the following stars have been proximately determined. I give them in a tabular form, with their parallax, the name of the observer, and the number of years required for light to come from the star to us:

Stars.	Parallax.	Observers.	Years.
	″		
α Centauri	0. 915	Henderson	3. 6
Do	0. 918	Maclean	--------
61 Cygni	0. 348	Bessel	9. 4
α Lyrae	0. 261	Struvè	12. 6
Sirius	0. 230	Henderson	21. 9
1830 of Groombridge's Catalogue	0. 226	Peters	22.
ι Ursæ Majoris	0. 133	----do	24. 8
Arcturus	0. 127	----do	25. 9
Polaris	0. 067	----do	31. 1
Capella	0. 046	----do	71. 7

The parallax bears no definite ratio to the magnitude of the star. The severest scrutiny of the bright star *α* Cygni, by the powerful instruments of Peters, shows absolutely no indication of any measurable parallax.

We can now give at least a partial answer to the question, how far off are the stars? An infant is born, and at the same time a beam of light starts from the bright star in the Swan on its way to our distant world. The child passes through the slow-recurring stages of life, reaches manhood and old age, and lingers his full century and dies; and the light has not yet reached us! Such is the distance which we vainly try to contemplate.

We may also give a partial answer to the question, how far off may a star be seen? Photometric measurements, deemed reliable, show that Sirius would be as bright as an ordinary star of the sixth magnitude at ten times its present distance; the light would then be 220 years in coming to us. But Sir John Herschel's twenty-foot reflector, and still more the great telescope of Lord Rosse, would bring out a star of the sixth magnitude at seventy-five times its present distance. Hence Sirius might be seen at 750 times the distance which now intervenes between it and us. To traverse so vast a space light would require the long period of 16,500 years! But why should we stop here? No law of the universe bars our progress. And yet, again, what were the use of attempting to advance farther? The steps become so vast that we hesitate to take them. We labor under the oppressive conviction that, if millions of them were taken, we reach no end. There is every presumption in favor of the hypothesis — nay, there is positive inductive reason for believing, that, from groups of stars and nebulæ, light reaches the human eye which has been 100,000 years in its tireless flight from the distant verge of the universe.

From what we now know, can we then doubt that the stars which beam effulgently upon us, or merely twinkle from the serene depths of ether, are great central suns? Nay, that many of them are great central suns, far surpassing our own in their intrinsic splendor? Wollaston has shown, by photomdiscal measurements, in Herschel's opinion, "apparently unobjectionable," that the intrinsic splendor of α Centauri is equal to nearly $2\frac{1}{2}$ suns, and that Sirius is probably equal to 63 suns. Such is the vastness and the grandeur of the starry heavens. We look upon the millions of those brilliant orbs, which, scattered through illimitable space, light up the universe of God, and these are but parts of His works! What, then, do they tell us of time and space, of infinite intelligence, and omnipotent power! Well might we ask with the patriarch, "canst thou by searching find out God unto perfection?"

There is one other topic to which I shall briefly allude, it is that of *double stars*. We here speak of stars connected together so as to form a system, not of those which are only optically double, in consequence of the two being nearly in the same direction. Of the double stars, which evidently form systems of their own, some are binary, consisting of two stars; some triple, and others, perhaps, quadruple.

Sir William Herschel was the first to recognize the importance of this particular branch of stellar astronomy, and the first to enter upon it. He made a catalogue of 500 double stars, which were suspected to have motions of revolution about each other. Since his time the catalogue, by the labors of Struvè, Peters, and others, has been extended to 3,000. Two observed elements indicate a motion of revolution of two stars, the one about the other, or both about their common centre of gravity. The first is a variation of the angular distance between them, and the second is a progressive rotary movement in the line joining them. Both these elements of position can be observed with great precision. The first will tend to develop the form of the orbit, the second the time of revolution. If the plane of the stellar orbit should chance to be perpendicular to the visual ray, we shall see

it developed in its true form. If that plane should coincide with the visual ray, then, whatever the real form of the orbit, it would appear to us to be a straight line. The companion would make a transit across the principal star, or be occulted by it every semi-revolution. It is now well known that, in the binary systems, the stars revolve in elliptical orbits. Of this class Sir John Herschel gives a catalogue of 15, in which the periodic times and the forms of the orbits have been proximately determined. The periodic times vary from 31 to 736 years. γ Leonis, not included in his catalogue, indicates a period of 1,200 years. Of these stars, some have completed more than a revolution since their orbits were computed. One of the most interesting of the double stars is γ Virginis. The companion passed the perihelion of its orbit in 1836, when no telescope in Europe could separate the two. The periodic time is 182 years, the major axis 3″.5, the orbit very elliptical.

Fig. 21 gives a view of the respective positions of the companion from 1830 to 1844.

Fig. 21

These orbits of the double stars furnish the most conclusive evidence that the law of gravitation controls the movement of the most distant stars no less than the orbits of the component members of our own system. It is truly and emphatically the law of *universal gravitation*, and binds together, in the strictest sense, the material universe of God.

Such are the methods by which we ascend to the vast heights of sidereal astronomy, and such are the lofty conceptions which it gives us of the works and attributes of the Great Creator.

MEMOIR OF PRIESTLEY.

READ BEFORE THE NATIONAL INSTITUTE OF FRANCE BY M. CUVIER, JUNE 27, 1805.

[Translated by C. A. Alexander.]

[The discourses by which the French Academy of Sciences is accustomed to commemorate its deceased members, whether native or foreign, constitute, it is known, a body of highly interesting biographical and scientific literature. Far from being limited to encomium, as the title of "Eloges," by which they are usually called, might suggest, they maintain a tone of candid criticism, and in dispensing justice to scientific discoverers deal in enlarged and original views of science itself. The names of their authors—of Delambre, Fourier, Cuvier, Arago and others—would teach us to expect no less.

Those delivered by Arago, late perpetual secretary of the academy, have been recently translated and published in England among the works of that distinguished and lamented individual. A few others may be found dispersed through the volumes of scientific periodicals of Great Britain, but as these are little accessible to the general reader, and as many have not been translated which well deserved to be so, it has been thought that a more extended collection than has yet appeared would not be unacceptable to the literary public.

In this view, a translation, not indeed of the whole series, but of such as, having not been already published in this country, may serve to give a connected and popular exposition of the progress of science, has been undertaken at the suggestion of the Secretary of the Smithsonian Institution; and the proposed work will appear under the auspices of the Institution, in so far, at least, as to guarantee the correctness of its views and the fidelity of its execution.

As a specimen of the work, as well as for its own intrinsic interest, the following memoir of one of the most original and ingenious promoters of modern science, who closed his eventful life in our own country, is appended to the present report.]

JOSEPH PRIESTLEY, the subject of the present discourse, was an English clergyman, whose important discoveries in physics occasioned his being chosen a foreign associate of the Academy of Sciences of Paris, and the National Institute lost no time in associating him with itself by the same title.* As he belonged besides to most scientific academies of his time, it may be that the homage which we this day render him has been already offered to his memory in all the great capitals of the civilized world.

This unanimity of commendation will appear the more encouraging

* The Academy of Sciences, with its kindred bodies, having been suppressed by a decree of the convention in 1793, was replaced in 1795 by the National Institute, divided at first into classes, which, on the restoration of the monarchy, again received the name of academies.—TR.

to the friends of enlightenment, and attest more strikingly the irrepressible influence of true merit, when it is considered that he who was its object used no address or management in securing it; that, on the contrary, his life was one of almost ceaseless controversy; that he seemed on all occasions to take pleasure in contesting the most accredited opinions, and attacked without scruple the most cherished interests of certain classes of men.

It is true that this excessive ardor in the assertion of his own ideas drew upon him the bitterest resentments, exposed him to all sorts of calumny, and more than once rendered him the victim of cruel persecution. A mob, excited by the false reports of his enemies, snatched from him in a single day the fruits of all his labors, and only by withdrawing from his country did he succeed in baffling the fury of his persecutors. But when his own countrymen seemed to forsake him, there were others eager to offer him an honorable asylum. And now, when the principal literary institution of a nation at war with his own, tenders him through my voice the last sad tribute which it owes to all its members, I see among the audience many to whom Priestley has been heretofore opposed, who yet seem to join their suffrages with mine and crown by their generous concurrence the measure of his triumph.

Science and philosophy will have nothing to fear from their bigoted adversaries so long as such a recompense shall await the man who has enlarged the noble edifice of our knowledge; so long as genius shall be regarded apart from its merely local relations, and the development of new truths shall procure indulgence for any incidental waywardness, singularity or even rashness of opinion; for it must not be dissembled that in matters of opinion Priestley has made himself liable to exceptions of this nature.

In effect, his history will exhibit him in the light, as it were, of two different—I had almost said, two contrasted—individuals.

One, the circumspect observer of nature, confines himself to the examination of objects which lie within the domain of experience, subjects every procedure to a strict and cautious logic, indulges neither in speculation nor prejudice, but seeking only truth, whatever it may be, seldom fails to discover and to establish it in the most satisfactory manner: the other shows us the adventurous theologian, who grapples boldly with the most mysterious questions, rejects authority however consecrated by the respect and belief of ages, and, abandoning himself to the heat of controversy, with opinions formed in advance, evinces as much solicitude for the success as concern for the validity or even consistency of his hypotheses. The former calmly resigns his discoveries to the examination of the learned, and finds them received without hesitation and his own merit acknowledged without contradiction: the latter invests himself in the warlike panoply of erudition and metaphysics, attacks with little discrimination whatever sect or dogma presents itself, and too often revolts the conscience by the aggressive zeal with which he seems bent on subduing it.

It is against the divine, the minister of peace, that all are in arms;

he is accused of exciting animosity, arousing vengeance, and troubling society. The physical inquirer, on the other hand, meets with invariable respect; every one acknowledges that, in the defence of truth, he relies only upon reason, that his discoveries are directed solely to the welfare of his fellow-men, and that his writings breathe nothing but a spirit of candor and of modesty.*

Thoroughly to know Priestly, then, it is necessary that he should be sketched under both these characters; that the theologian, metaphysician, and politician should be reproduced, no less than the ingenious physicist and associate of the National Institute. At the same time there can be no mistake as to the comparative prominence which should be given, on the present occasion, to one or the other, and as little probably as to the interest which posterity is likely to attach to them. He has himself somewhere remarked that, as a means of lasting renown, the labors of science are as far superior to all others as the laws of nature to the organization of societies; and that no statesman who ever rose to power in Great Britain has approached in celebrity its Bacons, Newtons, and Boyles; a maxim somewhat exaggerated, perhaps, but which it would have been fortunate if he had always kept before his own eyes. Priestley, however, is not the first celebrated man, whose judgment has shown itself incapable of mastering his character.

Mean while it is to be carefully noted that in no respect did his divergent opinions influence his conduct, but that, with the exception of the unmerited misfortunes which overwhelmed him in old age, the whole course of his life was alike uniform and simple. The mere list of his works would indicate as much; for, when it is known that he produced more than a hundred treatises, no one can suppose that society engrossed much of his time, or that his history can consist of much more than an analysis of his writings.

He was born at Birstal-Fieldhead, near Leeds, in 1733. His father was a cloth-dresser; his first master a dissenting minister. After several years study he obtained the situation of [tutor in the Belles Lettres†] at the provincial academy of Warrington, and afterwards became pastor of a congregation of dissenters at Leeds. Lord Shelburn, secretary of state and afterwards first marquis of Lansdowne, under a sense of Priestley's merit [which had then been established by his first discoveries] induced him to accept the position of [his lordship's librarian and philosophic companion, with a salary of £250, reducible to £150 for life should he quit the employment.] This connexion was terminated, without loss of confidence or friendship on either part, at the end of seven years, and Priestley resumed his pastoral functions among the dissenters at Birmingham. Here he

* Whether the contrast here presented be not pushed, in the spirit of antithesis, to too great a length, will probably be differently decided, according to the previous views of the reader. But that, in some of his metaphysical speculations and interpretations of prophecy, Dr. Priestley has laid himself open to the charge of temerity, will be denied by few; nor is it surprising that Cuvier should regret that such astonishing activity of intellect had not been restrained to the paths of induction, where he himself had found so secure a footing.—Tr.

† The words within brackets are from Lord Brougham's "Lives of Philosophers of the time of George III."

remained eleven years, up to the time of the disturbances which compelled him to quit that city and determined him to seek a refuge in the United States. Such is the brief yet complete outline of his private life; the history of his works, as it is more important, must be more extended.

The first of them were intended for the service of education, and an English grammar, his earliest production, is still used in the schools of Great Britain. His historic and geographic charts deserve to be used everywhere for the ingenious manner in which they represent the origin and fall of each State and the career of every celebrated man. His lessons on history evince both the comprehension and knowledge requisite for a profitable study of the revolutions of nations. Those on oratory and criticism are recognized as useful guides to the exercises of the young.*

This didactic form was that which he still employed in his first works on physics; his histories, namely, of electricity and optics, and his elements of perspective. The history of electricity was judiciously timed, for it appeared just when Franklin, by the boldness and success of his investigations, had thrown the brightest lustre around this interesting branch of physics, and as all that had been done up to that date was here presented in a clear and concise form, it was translated into several languages and first drew some notice in foreign countries to the name of its author.

The ungrateful task, however, of recounting what had been done by others was not long to limit the activity of Priestley. He proceeded without loss of time to place himself in the line of physical discoverers, and it was chiefly by his researches into the different kinds of air that he merited that title and established the most durable monument of his own renown.

It had long been known that many bodies give out air and that others absorb it under certain circumstances. It had been observed that the air of neglected privies and of the bottoms of wells, with that evolved by fermentation, extinguishes light and destroys animal life. A light air, also, had been observed in the interior of mines, floating mostly about the vaults of the passages, and kindling sometimes with fearful explosions. The former had received the name of *fixed* and the latter that of *inflammable* air. They are the same which we now call *carbonic acid* gas and *carburetted-hydrogen.* Cavendish had determined their specific gravity; Black had ascertained that it is the fixed air which renders the alkalies and lime effervescent; and Bergman had not been backward in detecting its acid properties. Such was the state of knowledge in these particulars when Priestley laid hold of the matter and treated it with a felicity altogether peculiar to himself.

Happening to be lodged, at Leeds, next door to a brewery, he had the curiosity to examine the fixed air which is exhaled from beer in

* Referring to these productions, Lord Brougham remarks: "It is difficult to imagine anything more adventurous than the tutor of an academy afflicted with an incurable stutter, and who devoted his time to teaching and theology, promulgating rules of eloquence to the senators and lawyers of his country."

fermentation, with reference to its deleterious influence on animal life and its property of extinguishing the flame of candles.

His experiments having given him some remarkable results, he was induced to extend them to inflammable air.

In aiming to determine all the circumstances in which these two kinds of air manifest themselves, he soon remarked that in many instances of combustion, especially during the calcination of metals, the air in which such operations are conducted is altered in its nature, without there being either fixed or inflammable air in the product. Hence his discovery of a third species of deleterious air, which he named *phlogistic air*, and which has been since called *azotic* (or nitrogen) gas.

He had availed himself of small animals to test the pernicious action of these different products, and was thus obliged to give pain to sentient beings. His character is displayed in the joy which he felt when the discovery of a fourth species of gas enabled him to dispense with this cruel expedient. This was *nitrous air*, which has the property of suddenly diminishing the volume of any other with which it mixes, very nearly, in the proportion in which that other air is respirable, and which consequently affords the means of measuring to a certain point the degree of salubrity possessed by different kinds of air.

This discovery, which was the origin of that branch of physics known as eudiometry, was of great importance; all the natural sciences were interested in possessing such a measure, and medicine, above all, might have turned it to account but for the difficulty of introducing scientific processes into the practice of even the most scientific arts.

Combustion, fermentation, respiration, and putrefaction are found to produce sometimes fixed air, sometimes inflammable, and sometimes phlogistic air. There is thus no end to the causes which may vitiate the atmosphere, and yet its purity has undergone no sensible alteration during all the time those causes have been acting. Hence it follows that in nature there must exist some constant means of restoring that purity.

Priestley detected these means in discovering that vegetables possess the property of decomposing fixed air during the day, and that they thus purify the atmosphere. This property, besides being the first key to the whole vegetable economy, when taken in connexion with that exerted by animals of vitiating the air by respiration, disclosed then, what has since been better developed, that the restorative energies of life consist chiefly in a perpetual transformation of elastic fluids.

Thus these discoveries respecting air opened an altogether new field to the researches upon living bodies, and shed a light on physiology and medicine till then unknown. But still more unexpected and brighter rays were soon to issue from the same focus.

Having applied the heat of a burning-glass to the calx of mercury, Priestley had the good fortune to obtain, in a pure and isolated state, that respirable constituent of atmospheric air which animals consume

vegetables restore, and combustion alters. He named it *dephlogisticated air.*

The other aeriform fluids which differed from the atmospheric air had been found to extinguish lights: this caused them to burn with a brighter flame and with wonderful rapidity. The others deprived animals of life: in this they lived longer than in even the common air, without need of renewing it, while their faculties seemed to acquire from it a greater energy. For the instant it was imagined a new means of existing, and perhaps of prolonging life, had been discovered, or at least an assured remedy against the greater part of the maladies of respiration.

This hope has proved deceptive, but dephlogisticated air has not the less remained one of the most brilliant discoveries of the eighteenth century; it is this which, under the name of oxygen, modern chemistry regards as one of the most universal agents of nature. By its means all combustion and calcination are effected; it enters into the composition of all acids; it is one of the elements of water, and the great reservoir of fire; to it we owe almost all the artificial heat which we procure in common life and in the arts; this it is which, in respiration, gives to all animated bodies their natural warmth and furnishes the material principle of their movements. The energy of different kinds of animals is in proportion to the force of its action upon them, and in the growth of vegetables there is no period when they do not combine with or disengage it in different manners. In a word, physics, chemistry, and physiology, both animal and vegetable, have scarcely a phenomenon which they can entirely explain without the element in question.

What has been said is but a slight sketch of the most remarkable discoveries of Priestley; time forces us to neglect a multitude of others which would of themselves furnish ample materials for the eulogy of another man. Each of his experiments has proved fertile in consequences, and it can scarcely be doubted that there are some of them which only await a closer attention to become the germ of new and important deductions.

His labors, as might be expected, were received with general interest; his works translated into all languages, and his experiments repeated, varied, and commented upon by the ablest inquirers. For his earlier researches on phlogistic air the Royal Society had awarded him Copley's medal, which is bestowed for the most important physical labor made public within the year, and which England regards as the noblest prize of scientific merit. The Academy of Paris accorded him a prize not less noble, and, because rarer, of more difficult attainment, the place of one of its eight foreign associates; an object of competition to all the scientists of Europe, and whose list of names, commencing with those of Newton, Leibnitz and Peter the Great, has never degenerated from that original splendor.

Priestley saw with surprise this accumulation of honors and modestly wondered at the multitude of precious truths which nature seemed to have reserved for his sole discovery. He forgot that her favors are never gratuitous, and that if she had so freely disclosed herself, it was because he had known how to extort her answers by the

indefatigable perseverance of his inquiries and the number and variety of his expedients. While others sedulously conceal how much they owe to hazard, Priestley seemed inclined to credit it with everything. He tells us, with unexampled candor, how often he was indebted to it unconsciously, how often new substances presented themselves to him without being recognized; nor does he ever dissemble the erroneous views which sometimes governed him and from which he was only detached by further experience.

These avowals did honor to his modesty without disarming jealousy. Those, whose own views and methods had proved abortive in discovery, called him a mere experimenter without method or design; no wonder, they observed, if, among so many trials and combinations, some should be lucky.

But the true physicist is not to be duped by such interested criticisms. He is well aware how many efforts it costs to arrive at those happy ideas which are the source and regulating principle of all others; while the very men who have thought fit to augment our admiration of their own great achievements in science by the luminous order in which they propound them, will be far from taking it amiss, that others, like Priestley, have chosen to give us their discoveries just as they made them, and have ingenuously retraced all the windings of the path over which they have travelled.

This peculiarity results from his manner of composition. We have here no finished construction, no digest of theorems rigidly deduced the one from the other, as they may be supposed to present themselves in the conceptions of pure reason. What he has given us is the journal of his thoughts in all the disorder of their succession, wherein we see him at first feeling his way in profound obscurity, spying out the faintest rays of light that he may collect and reflect them, sometimes misled by a treacherous and transient glimmer, but sure to arrive in the end at some region of vast extent and fertility.

Should we be displeased if the great masters of the human race, an Archimedes or a Newton, for instance, had thus admitted us to the confidence of their genius? Newton, when asked how he arrived at his great discoveries, replied, "By long thinking about them." With what pleasure should we not have learned that long series of thoughts by which Newton was conducted to that master thought which has inspired the meditations of all his successors. If his works at present teach us to appreciate the forces of nature, we should, by thus knowing the actual processes of his mind, have been enabled thoroughly to comprehend that noblest of nature's works—the genius of a great man.

We must not suppose, however, that the discoveries of Priestley were all perceived by himself, or that they were set forth in his writings as clearly or in the same manner as we should now state them. At the time of making them he knew no chemical theory but that of Stahl, and this, being founded on experiments in which air was taken no account of, was of course incapable of providing for its phenomena. Hence there results a degree of hesitation as to principles, and of embarrassment and uncertainty as to results. Seeking everywhere for phlogiston, Priestley is obliged to suppose it differently constituted

He finds it now in fixed air, which is heavy and acid; now in inflammable air, which is light; and again in phlogisticated air, which has no property of the other two. Sometimes there are cases where an accumulation of phlogiston diminishes the weight of the combination and communicates an absolute levity to the mixture; in other cases it produces a directly contrary effect. Thus there is no uniformity, nor is it possible to arrive at any general and precise conclusion.

That conclusion it was left for modern chemistry to draw, and for this purpose it has needed but one or two formulas. *There is no such thing as phlogiston; pure air* (or oxygen) *is a simple substance, as are also phlogisticated air and inflammable air; combustion is only the combination of pure air with combustible substances.* These few words have served to disembroil the chaos; every fact has fallen into its proper place, and chemistry has emerged in the fair and consistent form in which we possess it.

But chemistry, like the gods of the pagans, could create nothing out of nothing; elementary material was still needed for its disposal, and this material, Priestley, beyond all others, has furnished. Under this point of view, therefore, he may justly be considered one of the fathers of modern chemistry and be worthily associated with the authors of that celebrated revolution in science. He was a father, however, who never consented to recognize his offspring.

His perseverance in combatting on behalf of his original ideas has probably no parallel. Without being shaken in his convictions he saw the most skilful defenders of those ideas pass into the opposite camp; and when Kirwan, the last nearly of all of them, abjured the phlogistic doctrine, Priestley, unsupported and alone, still occupied the field and addressed a new defiance to his opponents, the principal French chemists of his time.

This challenge was at once taken up and replied to by Adet, who was then ambassador of France to the United States, and thus proved himself a worthy representative of French chemistry. The new arguments of Priestley against that theory originated, in fact, from his own want of familiarity with the operations of more recent chemistry, however ingenious and dexterous he might be in those processes which he had himself created. When he drew fixed air from substances into which he did not suspect it of having entered, he would deny that it invariably owes its origin to the carbon. And in forming water from oxygen and hydrogen, though a small quantity of nitric acid was always present, he would take no account of the portion of azote which produced it.

His later writings failed, accordingly, to bring back to his opinion any of those who had abandoned it. Like so many others who have endeavored to arrest movements first communicated by themselves, he experienced that ideas once dispersed abroad are as the seed whose product depends upon the laws of nature, and not the will of those who have scattered them. To which we may add that, when they have once taken root, no human power is any longer capable of eradicating them.

It remains now to trace, with painful interest, the career of Priestley in that other branch of his labors to which reference has already

been made. We have just seen him marching from one success to another in the cultivation of the merely human sciences, which he looked upon only as the employment of his leisure moments. We must now observe him engaged in the struggle to unveil those first principles which the nature of things hides from our reason beneath the folds of impenetrable mystery, striving to force the world into an acceptance of his conjectures, consuming almost his whole life in these fruitless efforts, and sinking at last into an abyss of misfortune.

Every indulgence will be here needed as well for the recital as its subject. It may even appear to some that such details are out of place before this audience; but where else ought the admonition they afford to be listened to with more interest?

It has been already said that Priestley was an ecclesiastic; it must now be added that he passed successively through three creeds or forms of belief in arriving at one which he could conscientiously adopt as the basis of his teachings.

Reared in all the severity of the Presbyterian communion, which is called Calvinistic in France, he passed at the age of twenty years into the ranks of Arianism. * * * * Arianism, while holding Christ to be a creature, regards him as a Being of superior nature, produced before the world, and himself the organ of the Creator in the production of other beings. It is the doctrine which the "Paradise Lost" has invested with so magnificent a garb of poetry. Priestley professed it for a length of time, and then abandoned it to become what we should call in France, a Socinian. Few, perhaps, of those who hear me know in what these two sects differ; but the Socinians deny the pre-existence of Christ, and regard him only as a man, though they revere in him the Saviour of the world. This subtle distinction between two creeds occupied for thirty years a head which the most important questions of science might rightfully have claimed, and was to Priestley the occasion of incomparably more pages than he has written on the different kinds of air. * * * * * * Nor was he less peculiar in the metaphysical part of his creed. It seems to have been demonstrated by the sounder metaphysics of modern times that it is impossible for the thinking substance to take direct cognizance of its own proper nature, just as it is impossible for the eye to see itself. For any such purpose, to contemplate itself or compare itself with other existences, it should be able to do so from without, while it is only within and through its own peculiar modifications that it perceives, or receives the impression of those existences. Priestley either overlooked or disregarded these conclusions. In his view, Scripture and experience agree in making the soul material; the fibres of the brain are the depositary of the images produced by the senses, while the power which these fibres possess of communicating their vibrations to one another is the source of the association of ideas. Sensation perishes with the body, but will revive with it at the day of resurrection, in virtue of the will and power of God. Till then we shall sleep in absolute insensibility; the distribution of punishments and rewards awaits us only thereafter.*

* It should be remarked that the above is far from being an accurate representation of the materialism of Priestley, which should not be confounded with the grosser forms of that doc-

A material soul must necessarily be submissive to exterior impulses, and thus absolute necessity, not free will, becomes the law of our determinations. If rewards and punishments are attached to our conduct it is only to give one more determining cause in favor of virtue.

These doctrins are, many of them, those of the earlier Socinians, to which Priestley only brought the support of new arguments. Without stopping to discuss questions so foreign to the ordinary studies of the Academy, and which it is enough to have briefly recalled, it is proper to say that he sustained his opinions with but too much skill. Even his adversaries give him credit for great erudition and singular dexterity in combining and disposing of his resources, and look upon him, therefore, as one of the strongest controversialists and enemies of orthodoxy in these latter times. * * * * *

It might be thought that in rejecting so many opinions Priestley had but one more step to take to fall into the most absolute incredulity. But this he never did; on the contrary, it seemed to please him to occupy, in theology as in physics, a post by himself, which, however perilous, he distrusted not his own courage or ability to defend. Those who went farther than himself or not so far, the orthodox and the skeptical, were alike the objects of his attack, and wherever, in all Europe, anything appeared which seemed to menace, in the least degree, either revelation in general or his own manner of interpreting it, *that* he felt himself called upon to refute. His activity in this species of warfare was without bounds; atheists, deists, Jews, arians, quakers, methodists, calvinists, church of England men, and catholics, were all taught to recognize him as an opponent. There are publications of his against each of these forms of belief, the very titles of which it would be almost endless to recite.

A proof that all this was done in good faith is the fact that he thought himself authorized to predict from Scripture events that were near at hand. Prophets who have not his confidence take care to postpone the accomplishment of their predictions, so as not to have them falsified during their own lifetime. But Priestley felt more secure of his facts; he published, in 1799, an address to the Jews, in which he announced to them, from the revelations of Daniel and St. John, their speedy re-establishment in Palestine, with a reunion of all creeds and the foundation of a reign of glory. Besides the calculation according to years, which referred this great event to the commencement of the nineteenth century, it was to be heralded by such tokens as the destruction of the papal power, of the Turkish empire, and of the kingdoms of Europe. The French monarchy, firm as it seemed, had already fallen; the rest would soon follow; the Pope was dethroned and in exile; the Turk only subsisted through the compassion of his neighbors. Priestley lived long enough to see the failure of at least a part of these supposed tokens.

Details like these, however extraordinary, could not be passed in

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trine. He had adopted the theory of Boscovich, as presented in the *Theoria Philosophiæ Naturalis*, &c., 1758, according to which, matter consists in emanations of force from definite portions of space, and is in reality devoid of any other substratum.—Tr.

silence, for the *eloges* of the Academy are historic, and, as was expressly prescribed by the first and most illustrious of our predecessors, are bound on every occasion to a fair exposition of the *pro* and *con.* Nor can it be otherwise than useful to observe, as in the present example, to what lengths the finest genius may be misled when it attempts to overleap the limits which Providence has prescribed to our understanding. There is even more instruction in the errors of such a man as Priestley than in his actual misfortunes; for where is the generous mind that would not suffer even greater misfortunes than his if it were only sure of having announced truth and vindicated right?

Yet it was not precisely the theology of Priestley which occasioned his misfortunes; in England every one dogmatises as he pleases. It was his politics, too closely allied to that theology; the politics of dissenters being in almost every case the politics of opposition.

We have been accustomed, in France, to consider protestants as republicans from religion; they are only so from oppression. In Ireland it is the catholics who pass for republicans, while the protestants, who rule, are royalists, because the king is of their party. This natural opposition is more vehement in England than elsewhere, precisely because there dissenters are tolerated by halves, and only by halves. Excluded from honors and employment, they are constrained to the rigid payment of tithes for a form of worship which is not their own. Their children are not even admitted into the national universities, and yet, influential both from their numbers and wealth, they are left at full liberty to assemble, to debate, to print—to exercise, in fact, every means of inflaming their resentments.

For thirty years Priestley was the most eloquent, bold, and persevering organ of their grievances. He put forth twenty volumes in this service. In this service solely did he write against the celebrated treatise in which Burke predicted in so true and startling a manner the evils which must flow from the French revolution. Apparently the object of Priestley's reply was not well understood in France, for he owed to this his nomination as French citizen and member of the convention, two titles which, at that time, seemed to sit but ill on so warm a defender of revelation and universal toleration. The first he did not decline, but the exercise of the second was evaded on the plea that he did not sufficiently understand the French language.

Without pronouncing as to the substance, it must be conceded that the political writings of Priestley unite a rare moderation in terms to a consistency of principle not less rare. He asks nothing for dissenters which he does not equally ask for catholics, and with more urgency for the latter as the greater sufferers. No catholic has more vividly painted the oppression under which nine-tenths of the Irish people labor.

I know not what gratitude the catholics may have evinced for these efforts of a unitarian in their behalf, but this extension of his good will had no tendency, we may well conceive, to reconcile him with the Anglican party. To the high churchmen he had become by these means the object of a concentrated hostility; those who wrote

against him were held in peculiar favor, and in some cases were, on this very account, rewarded with prelacies; which led Priestley pleasantly to observe "that he might be considered as holding the portfolio of such benefices in his own hands." But the aversion he inspired did not stop within these venial limits; there is too much reason to think that the popular turbulence of which he was the victim was greatly fomented by the intemperate writings and discourses of ministers of the establishment.

The first movements of the French revolution had at that time wrought division, not only in France, but in all the States, cities, and even families of Europe. As yet there was no outbreak but in France, but men disputed everywhere, and, strange to say, it was precisely in the freest countries that the greatest ardor for revolution manifested itself. Under these circumstances the partisans of the British government had recourse to means of which the enemies of government in France were setting a successful example, and prompted the popular riots by which the revolutionists, or those suspected of being such, were assailed.

Not the least formidable of these riots was that which occurred at Birmingham, July 14, 1791. A banquet was given on that day by persons of different sects, including some episcopalians, to celebrate the anniversary of the attack upon the Bastile, and it was reported that Priestley was the chief promoter of the festival. As his enemies had spared no means of inflaming the popular mind, resorting even to the fabrication of tickets of invitation replete with sedition, and of toasts steeped in criminality or absurdity, a heated crowd is soon collected; the calumny circulates and is aggravated by the most odious imputations; and the tavern finally, where the guests are assembled, is assaulted and sacked. The furious multitude exclaim aloud against Priestley; he is the organ of dissent, the file leader of revolution, the man against whom has long been levelled the hatred of every true friend of his country. The moment has arrived when they can avenge themselves.

The unfortunate philosopher, so far from participating in the dinner, was ignorant of what was imputed to him and of all that was passing in the city. But an excited rabble listens to nothing; they conclude that he has taken flight, and proceed with torches and other instruments of destruction to his mansion.

This was a modest retreat, half a mile in the country, where he lived with his wife and two sons in the simplicity of ancient manners. Here it was that he had received the homage of men illustrious by birth or merit, none of whom would have been content to leave England without seeing him; and here for eleven years he had divided his time between the pursuit of science, the instruction of youth, and the exercise of that charity which he considered the first duty of his ministry.

Here there was only one ornament to be seen, only an incomparable one; the rich collection of instruments, in great part devised and constructed by himself; the focus from which had radiated so many new truths, and which had diffused inestimable benefits among those who now rushed to its destruction; for these were almost all artisans of

Birmingham, and among the numerous manufactures of that city, there is scarcely one which does not owe some improvement in its processes to the discoveries of Priestley.

But what avails gratitude against the spirit of party, or does the people know ought of services of this kind? All was laid in ashes; apparatus, in which experiments designed for the solution of important questions had been for months in process of development, records of the observations of many years, works in course of preparation, a large library, enriched with notes, additions and commentaries, were, in a few moments, with the house itself, utterly destroyed.

It was truly afflictive that such a man should thus see the fruits of forty years of honorable assiduity and wise economy suddenly snatched away—a loss not merely of his moderate fortune, which he might have disregarded, but of the works of his hand, the conceptions of his genius, the fund which he had reserved for the meditations and employment of his remaining life. Fortunately his family had been apprised of the approach of the mob, and had withdrawn him in time from the dreadful spectacle.

The riot continued three days, and the houses of his friends underwent the same fate with his own. As usual, it was the victims who were accused, and the public journals failed not to announce that there had been discovered among the papers of Priestley the proofs of a wide-spread conspiracy.

This calumny is sufficiently refuted by the fact that he openly resided two years more near London, in the college of the dissenters at Hackney, where he succeeded the celebrated Dr. Price in the professorship of chemistry. There was time enough to bring him to justice, and no want of zeal on the part of his accusers, if there had existed the slightest proof.

They confined themselves to painting him in the most odious colors in political pamphlets and periodicals. Few instances can be found of such overflowing rancor, nor would it be easy to credit this rage of defamation against a man who conferred so much honor on his country, had we not before our eyes the examples which the last fifteen years have furnished of the power of party spirit to envenom men's opinions, and those which the last fifteen centuries exhibit of the fury with which personal crimination may be urged when the pretext is religion.

Nothing in the character of Priestley seemed calculated to produce such hostility; his sentiments were never influenced by his controversies, as might be shown by his friendly intimacy with Dr. Price, though they had often written against each other. So far from any turbulence or haughtiness of manner, his conversation was always noted for the same modesty which pervades his writings, and nothing was easier with him than to say, *I do not know*—words which the generality of professedly learned men find it so difficult to pronounce. His countenance bore rather the impression of melancholy than of animation, though he was by no means indifferent to the company of his friends, and enlivened their intercourse with a natural and becoming gaiety. This man, so profound in many parts of science, passed several hours of each day in teaching the young. This was with him

a favorite occupation, and his pupils still revere his memory with filial tenderness, many of them with genuine enthusiasm.

But no consideration could induce him to pause when he thought there was some truth to be defended, and this trait of character, so admirable in itself, destroyed the effect of more amiable qualities and constituted the torment of his life; because he carried it to exaggeration, and because he forgot that reasoning is the least of the means which must be used to make men adopt opinions which conflict with their habits of thought or temporary interests.

The insults heaped upon him, and the fear of again compromising the lives and fortunes of his friends, at last made a sojourn in his own country intolerable. In his new engagements at Hackney, industry and patience might repair, as they had already in part repaired, the disasters of Birmingham; but this consideration was not sufficient to detain him; and as coming to France during the war would have given countenance to the charges of his enemies, he could see no chance of repose except in the United States of America. Yet was it some time before he found it even there; English prejudices followed him beyond the seas, and not until the accession of Jefferson to the Presidency was he free from the apprehension of being obliged to quit that asylum.

The dedication of his Ecclesiastical History to that great magistrate, in acknowledgment of the tranquillity restored to him, and the reply of Jefferson, afford a noble specimen of the relations which may subsist between men of letters and men in place without humiliation to either.

Priestley proposed to consecrate the rest of his life to the work just mentioned, in which he intended to comprise the development and proofs of all his theological opinions; but he was arrested at the fourth volume by a fatal accident. His food, by some unknown means, proved one day to have been poisoned;* his whole family was placed in jeopardy, and his own health languished from that time forward. A gradual decay terminated his life after three years of suffering. He died at Northumberland, in Pennsylvania, February 6, 1804.

His last moments were marked by the effusions of the same piety which had animated him through life, and which, from not being well regulated, had occasioned all its errors. He caused the Gospels to be read to him, and thanked God for having granted him a useful life and peaceful death. Among his chief blessings he ranked that of having personally known all his celebrated cotemporaries. "I am going to sleep like you," he said to his grandchildren, who were brought to his bedside; "but we shall all awake together," he added, looking towards the attendants, "and I trust to everlasting happiness." These were his latest words, and they bear witness to the belief in which he died.

Such was the end of a man whom his enemies accused of wishing to subvert all religion and morals; but whose chief fault was to have misconceived his vocation, and to have attached too much importance

* The statement made here, as well as in some other works, of the poisoning which occasioned the decline and death of Dr. Priestley rests on little or no authority.—*Translator.*

to his private sentiments in matters where the most important of all sentiments must be the love of peace.

[NOTE.—We are informed by Lord Brougham that, on settling at Warrington, "Priestley married the daughter of Mr. Wilkinson, a respectable iron master in Wales. She was an amiable woman and endowed with great strength of mind, which was destined afterwards to be severely tried." By her he had three sons and one daughter, of whom the youngest son, Henry, the peculiar companion of his father's agricultural labors at his new home, in Pennsylvania, died at the age of eighteen, in 1795. The mother died ten months later. "These blows," says Lord B., "though he felt their weight, did not at all crush him; his resignation was exemplary, and his steady, enthusiastic faith in revelation gave him a certain hope of meeting, before many years should elapse, with those whom he had lost. It was, indeed, quite evident that religion was as much an active principle in him as in any one who ever lived. Not only is it always uppermost in his thoughts, but he even regards temporal concerns of a public nature always in connexion with the Divine superintendence, and even with the prophecies of Scripture. His letters are full of references to those prophecies as bearing on passing events, and he plainly says that, since his removal to America, he should care little for European events but for their connexion with the Old Testament. He also looked for an actual and material second coming of Christ upon earth."

The descendants of Dr. Priestley appear, from an account received through the courtesy of a grandson, Joseph R. Priestley, to be widely dispersed. Not only do several of them remain in his native country, at London and Birmingham, but others are to be found at Northumberland, Pennsylvania, where he settled in this country; at New Orleans; at Atlanta, in Georgia; and even at Melbourne, in Australia. He was buried at Northumberland, and the following is the inscription on his tomb:

To
The memory of the Reverend
DR. JOSEPH PRIESTLEY,
Who departed this life on the 6 Feb., 1804,
Anno ætatis LXXI.

"Return unto my rest, oh my soul, for the Lord hath dealt bountifully with thee: I will lay me down in peace and sleep till I awake in the morning of the resurrection."]

INSTRUCTIONS IN REFERENCE TO COLLECTING NESTS AND EGGS OF NORTH AMERICAN BIRDS.

INTRODUCTORY REMARKS.

The Smithsonian Institution is desirous of collecting as full a series as possible of the nests and eggs of birds of North America, with the view not merely of exhibition in its museum, but to furnish materials for a work on North American Oology, in preparation by Dr. Brewer, of Boston, and to be published in successive parts by the Institution.

This memoir is intended to give an account of the geographical distribution of North American birds, as well as of their habits and peculiarities during the breeding season, and to be accompanied as far as possible by accurate figures of the principal varieties of the egg of each species, based upon photographic drawings. Of this work, the first part, embracing the *Raptores* (vultures, hawks, and owls,) and *Fissirostres*, (swallows, swifts, and goatsuckers,) is nearly ready for publication, and will be issued during the year 1859.

The object contemplated by the institution is not merely to procure specimens of eggs not previously in its possession, but also to obtain positive evidence as to the limits within which each species rears its young. For this reason it respectfully invites donations from all parts of the country of as many kinds of nests and eggs as can be procured, with the exception of a few of the very commonest species hereafter to be mentioned; and requests that special effort be made to procure a full series for each locality. As duplicate eggs of all kinds, and in any number, can be readily used in the exchanges of the Institution, and in supplying other cabinets, no fear need be entertained of sending more than enough for the purposes in view.

The eggs, of which a single set only need be collected for the present, are chiefly those of the eastern blue bird, (*Sialia sialis*,) the robin, (*Turdus migratorius*,) the cat-bird, (*Mimus carolinensis*,) the red-winged black bird, (*Agelaius phoeniceus*,) and the crow black bird, (*Quiscalus versicolor*.) Those to which particular attention should be paid as groups, are the hawks, owls, woodpeckers, small waders, ducks, &c., of all portions of the country; but, as stated, all kinds of eggs, and particularly those from the regions west of the Mississippi, and from the northern parts of America, are desired. A subjoined list embraces the specimens more particularly wanting to the collection of the Institution; those having an asterisk prefixed being, with rare exceptions, entirely unknown to science. The numbers in the list refer to a printed catalogue of North American birds, published by the Institution, which will be sent to any one who proposes to collect eggs for its museum.

In this catalogue about 720 species are enumerated as now known, while of these the eggs of more than five hundred are marked as desiderata, more than three hundred, or nearly one-half, being unknown in American collections. Among easily identified species most wanted are the California vulture (*Cathartes californianus*;) the swallow-tailed hawk, (*Nauclerus furcatus*,) and the black-shouldered hawk, (*Elanus leucurus*) of the south; the burrowing owl of the plains, (*Athene hypugaea*,) the ivory-billed woodpecker, (*Picus principalis*,) the western hairy woodpecker, (*Picus harrisii*,) the red cockaded woodpecker of the south, (*Picus borealis*,) the red-bellied woodpecker, (*Centurus carolinus*,) the red-shafted woodpecker or flicker of the west, (*Colaptes mexicanus*,) the Oregon robin or varied thrush, (*Turdus naevius*,) the California blue bird, (*Sialia mexicana*,) the Rocky mountain blue bird, (*S. arctica*,) the western nuthatch, (*Sitta*,) the fish-crow of Puget Sound, (*Corvus caurinus*,) all the jays of the Rocky mountain region; the Canada jay, (*Perisoreus canadensis*,) the band-tailed pigeon, (*Columba fasciata*,) the wild turkey of New Mexico, (*Meleagris mexicana*,) all the quails or partridges of western Texas, New Mexico, and Arizona; the whooping or white prairie crane, (*Grus americana*,) the glossy ibis, (*Ibis ordii*;) most of the snipes, sandpipers, curlews, and other small waders; the two species of swans, (*Cygnus*,) most of the geese and ducks; the booby gannet of Florida, (*Sula fiber*,) the wild pigeon, and many other species.

The following details will be found to contain all the instructions necessary to the preparation and preservation of oological collections:

INSTRUCTIONS FOR COLLECTING AND PRESERVING.

The nests of birds are to be sought for in all localities and in different months of the year, according to the latitude, May and June being generally the most productive. Many of the rapacious birds, however, begin to lay much earlier in the middle States, even in February and March.

When a nest containing eggs, or one newly constructed, is discovered, it should not be disturbed, if possible, before the parents have been observed hovering around or near, and thus identified. If the species cannot be otherwise positively determined, a parent bird should be secured, and either the whole skin be prepared, or a portion—as the head or wing, and preserved for identification. The whole bird may be thrown into alcohol, and thus easily kept.

The services of boys and other persons on farms, plantations, &c., may be called to great advantage into requisition in collecting eggs. Whenever they have found a nest, however, it should not be disturbed before information is communicated to and the spot visited by some one competent to determine the species, unless the parents can be taken with the nest. No pains should be considered too great to secure the certain identification of each set of eggs. If, however, this identification should be impossible, the eggs should still be preserved, as the species can usually be approximated to, if not absolutely determined, by an expert oologist.

Sometimes by removing all the eggs in a nest, except one or two, without handling those left, quite a large number can be obtained from one pair of birds; generally, however, the nest will be found abandoned on a second visit.

The nests may not always be removable, and in such cases, full mention of their position, character, &c., should be carefully made. Nests constructed in bushes or on trees usually need but slight precautions for their preservation intact. Those on the ground often require to be secured against falling to pieces by a little judicious tying together, or even by a few coarse stitches with a thread and needle. A little cotton packed in the nest above the eggs will generally keep the latter whole until reaching home, unless subjected to a violent shock. It will be safer, however, to enclose each one in an envelope of cotton.

It is absolutely necessary, in all cases, to empty every egg of its contents, in order to preserve the shell for cabinet purposes; and this should be done at the earliest moment possible. It is accomplished in various ways: the simplest, when the egg does not contain a young bird, being to prick a small aperture at each end (or better, perhaps, on opposite sides) with a sharp needle, (a three-cornered one answers best,) one rather the larger, through which the contents are blown by the application of the mouth at the other. Delicate eggs, however, when fresh, can be best emptied by suction, a small quantity at a time of the contents being drawn into the mouth, and then discharged.

Should there be an embryo in the egg, or should the contents have become thickened by long standing, it will be necessary to make a larger aperture in the side by pricking out a circular piece of shell carefully with the needle. A smaller hole may then be made opposite to this, at which to apply the mouth in blowing, or the embryo may be picked out through a single large hole. It will be of much interest to preserve all embryos in alcohol for further investigation.

European collectors usually make two small apertures close to each other on one side, instead of on opposite sides. The discharge of the contents of the egg is facilitated by the use of a small conical blow-pipe or tube, the smaller end so fine as to enter the smaller aperture. A stream of water injected by the mouth through the tube into the aperture will be found an expeditious method of emptying the egg, but it must be conducted very carefully. When a large hole is made, the tube may be directed through it to the opposite side of the egg, and a current of water forced in this will soon discharge the contents. When practicable, the white membrane, the edge of which usually protrudes from the opening after the liquids are forced out, should be seized with a pair of forceps and pulled out, as, if left, it may discolor the egg, and will always attract insects. If not too small, the egg should then be partly filled with water through the tube, or by laying one hole against a saucer of water and sucking through the other, and carefully rinsed out. After the water is again blown out, the egg may be allowed to dry by placing the larger hole downwards on blotting or absorbent paper or cloth. When dry, the eggs should be replaced in the nest, or laid carefully away, care being taken to add

a number or other mark showing the locality, date, collector, and supposed species, as well as relationship to an embryo removed, or to any portion of the parent preserved. It will in most cases be best to attach the same number to nest, eggs, embryo, and parent belonging together. This mark may be made neatly on the eggs, itself with ink and a quill pen, or on a label carefully packed with them. A record book showing what has been taken and preserved, with dates and explanatory remarks, should always be kept.

In making the apertures in eggs that have peculiar markings, care should be taken to select some inconspicuous spot that will leave the pattern of coloration undisturbed. Eggs that are cracked may be greatly strengthened by pasting tissue or other thin paper along the line of injury, or what is easier, and in most cases even better, by brushing collodion along and over the cracks. It is often well to cover the punctures or holes cut out, especially if large, with thin paper or gold-beaters' skin. If a piece be removed, it can usually be easily replaced and kept in by pasting thin paper over it and the line of separation, or around the latter.

Notwithstanding the apparent fragility of eggs, a very little experience will enable any one to empty them of their contents with great ease and safety. The principal accident to be guarded against is that of crushing the egg by too great pressure between the fingers ; these should be applied so as to barely hold the egg, and no more. If the operation of emptying be performed over a full basin of water, the occasional dropping of the egg from the finger into the water will be attended with no harm.

To pack eggs for transportation, each one should be wrapped in a light envelope of cotton and laid down in layers separated by strata of cotton. They should be kept in rather small boxes of wood, or if pasteboard be used, these should always be transmitted in wooden boxes, as the eggs are thereby less likely to be broken by a sudden jar or shock. If the nest is sent along, it may contain the eggs belonging to it, each one wrapped in cotton, and the vacancy of the nest filled with the same or other light elastic material. It will be well to pin or tie up each nest in paper to keep it secure, and to prevent entangling of the materials when several are laid together. A temporary box may often be readily constructed of pasteboard, to contain the more delicate or valuable ones.

Whenever practicable, the embryos or young found in the egg should be carefully preserved in alcohol, great care being of course taken to mark the specimens properly. The better plan will be to keep each set in a small bottle or vial, and a slip of stiff paper or parchment placed inside with the number or name. Whenever the abundance of the eggs will warrant it, a large number with the young in different degrees of development, even as many as fifty of a kind, should be secured. The embryos in this case need not be removed from the egg, which should, however, be cracked at the blunt end to facilitate the entrance of the spirit. Researches at present in progress relating to the embryology of birds promise results of the highest interest in reference to ornithological classification.

SPECIAL DESIDERATA AMONG NORTH AMERICAN EGGS.

N. B. The asterisk (*) prefixed indicates that the egg of the species is either entirely unknown to science or scarcely to be found in any American collection. The numbers are those of the species in the catalogue of North American Birds published by the Smithsonian Institution, reprinted from the ninth volume of the Pacific Railroad Reports.

*2	51	*100	*163	*209	272	321	*379	*440	501	*562	611	666
*4	52	*103	*164	210	273	*322	380	*441	502	*563	613	*668
5	*53	*104	165	*211	*274	*323	381	*442	503	*564	*614	*669
*6	54	*107	166	*212	275	324	382	*443	*505	*565	*618	*670
7	*55	*108	168	213	*278	*327	*383	*444	*509	*566	*621	*671
*8	*56	*110	*169	214	*276	*329	385	*445	*510	567	*622	*673
9	57	113	*171	*215	278	*330	388	446	*511	*568	*625	*674
*10	*58	*115	*172	*216	280	*331	389	447	*513	*569	626	*675
*11	59	118	*173	*218	*281	*333	*392	448	515	*570	627	*676
12	*60	*119	*174	*219	*283	*334	*393	449	*516	*571	629	*677
14	*61	*120	175	221	*284	335	*394	450	520	*572	*630	*678
*16	*62	*121	178	*222	*285	336	*395	*452	521	*573	*631	*679
18	63	*122	179	*223	*286	339	397	*454	523	*575	*632	680
*19	*64	125	180	*224	*287	*340	398	455	*524	578	*633	*684
20	*65	*127	181	228	*288	341	402	*458	*525	579	*634	*686
*21	66	*128	*182	*232	*289	*343	403	459	*526	482	635	*687
*22	67	*129	183	234	*291	*345	404	460	*527	583	*636	*691
23	71	*132	184	*235	*292	346	405	*461	528	584	*637	*693
24	*72	*133	*185	236	293	*347	408	462	*529	*585	*638	*700
25	*73	134	187	239	*294	*348	409	463	530	*588	*639	*702
*26	*75	*136	*188	*241	*295	*350	410	*466	*531	*589	640	*704
27	*77	137	189	*242	*297	*351	411	467	*532	*590	*641	*705
*28	*78	138	*190	*243	298	*352	412	468	*533	*591	*643	*707
*29	*80	*141	*191	*244	*299	*353	413	*469	*534	*592	*644	*710
30	81	*142	*192	246	300	*355	*417	470	*535	*593	*646	*714
31	*82	144	193	247	*301	*356	422	473	*536	*594	647	*716
*32	*83	145	194	*249	*303	*360	423	*475	*538	*595	648	*717
*33	*84	*146	*195	250	*304	*361	*424	*476	*539	*596	*650	*718
*34	*86	*147	196	251	*306	*362	425	*477	540	*598	651	*720
*35	*87	149	*197	255	307	364	*427	*478	541	*599	652	*721
*36	*88	*150	198	256	*310	*365	428	479	*542	*600	*653	*722
*37	*89	151	*199	257	*311	*366	*430	*480	546	*601	*654	*723
*39	90	*152	200	258	*312	367	*431	*481	*547	*602	*655	*724
*40	*91	153	*201	262	314	*370	432	*482	*548	*603	656	*725
*41	92	*154	202	*263	*315	*371	*433	*488	549	*604	*657	*728
43	*93	*156	204	*264	316	*372	435	489	*550	*605	658	732 *733
47	95	*159	*205	*266	317	*373	*436	*494	*551	*607	*659	*734
48	*96	160	*206	267	318	*374	437	497	556	608	*663	*735 *736
49	*98	*161	*207	269	319	375	*438	498	*557	609	*664	*737
50	*99	*162	208	271	320	376	439	*500	*561	610	*665	738

INSTRUCTIONS FOR COLLECTING INSECTS.

INTRODUCTORY REMARKS.

The Smithsonian Institution has undertaken the preparation of a series of reports on the insects of North America, with the view of attracting attention to and facilitating the study of a department of natural history, which, though so much neglected, is yet of great practical importance to the agriculturist and rural economist. These works will consist—first, of catalogues of all the known genera and species of each order, with reference to the places of publication; and secondly, of monographs and detailed descriptions of both old and new species, so as to enable any one interested in the subject to identify the insects met with, and to prosecute investigations respecting them.

Towards the accomplishment of this object the Institution has already published a catalogue of the North American Coleoptera, by Dr. F. E. Melsheimer, and also one of the Diptera, by Baron Ostensacken, while similar catalogues of Neuroptera, Hymenoptera, Hemiptera, and Diurnal Lepidoptera are in an advanced state of preparation. It is now proposed to take up a very interesting and extensive group, that of the Moths or Night Butterflies, and contributions of materials towards a work on this subject are, therefore, respectfully solicited. There is no locality in the country where new species may not be readily obtained, and from which complete collections are not desirable, although novelties are most to be looked for from the regions of the west. From every region the most common and familiar species are equally desirable, with the rarest and most striking; the object being not merely to collect all the species, but also to determine accurately their geographical distribution.

In the following pages will be found special instructions for collecting insects, furnished for this article by different entomologists, with some general remarks on the subject taken from Samouelle's Entomologist's Companion.

GENERAL INSTRUCTIONS.

"Insects are so various in their habits that they may be found in every part of the world, at all seasons of the year, and in every situation.

As some localities are more congenial to their nature than others, I shall mention such as will be likely to furnish the best result to the Entomologist:

Woods, Hedges, and Lanes.—These situations furnish by far the greatest number of insects. In woods the Entomologist must beat the branches of trees into his umbrella, or folding net, and must select for this purpose open paths, the edges, &c. The trunks of trees, gates, and felled timber, should be carefully examined, as many of the Lepidoptera and Coleoptera are found in no other situations. Many rare and very beautiful insects are found in the hedges, in lanes, as also in the nettles, &c., which grow under them; these should be well beaten, especially when the white thorn is in blossom, in the months of May and June. Hedges in dusty roads are seldom productive.

Heaths and Commons.—Many insects are confined to these situations, not only on account of plants, which grow in such situations, but by the cattle and their dung, in the latter of which many thousands of insects may be found—mostly in the months of May, June, and July; these are principally Coleoptera.

Sand-Pits.—In such places will be found many minute Coleopterous insects, as well as wasps, &c.; the roots of grass, at which the former are found, should be closely examined.

Meadows, Marshes, and Ponds.—In meadows when the Buttercups (Ranunculi) are in blossom, many Dipterous and Hymenopterous insects are found. The drills in marshes should be examined, as many species of insects are found on the long grass, as also the larvæ of many Lepidoptera. Neuroptera are abundant in such situations, especially if any hedges or trees are near the spot.

The mud which is brought up from the bottom of ponds should be thoroughly examined, and such small insects as are found may be put in a small bottle filled with water, which will not only clean them but keep them alive. To the Entomologist this mode of collecting will be very advantageous, as he will thereby obtain many species of Dysticidæ, Notonectidæ, &c.

Moss, Decayed Trees, Roots of Grass, &c.—Many insects will be found in moss and under it; the roots of decayed trees afford nourishment and a habitation to a number of insects; many of the larvæ of Lepidoptera penetrate the trunks of trees; most of the Cerambycidæ feed on wood, as well as some species of Elaters, &c. In seeking for these a sharp digging instrument is generally used, as it is sometimes necessary to dig six or seven inches into the wood before they are found.

Banks of Rivers and Sandy Sea-shores.—These situations are productive of a great variety of Coleoptera, and other insects.

The dead animals that are thrown upon the shores should be carefully examined, as they are the food of Silphidæ, Histeridæ, Staphylinidæ, &c. May and June are the best times for collecting in these localities.

Dead animals and dry bones should be constantly examined, as these are the natural habitations of many insects.

Fungi, boleti, and flowers, should be carefully, when met with, examined, as many exceedingly rare insects inhabit them.''

[The preceding general remarks have been taken from Samouelle's Entomologists' Guide.]

INSTRUCTIONS FOR COLLECTING COLEOPTERA.

BY JOHN L. LE CONTE, M. D.

General Remarks.

The insects of this order are mandibulate, or furnished with jaws, and may be distinguished by the upper wings being converted into hard corneous shields, which protect wholly or part of the upper surface of the abdomen. They are very numerous, more than 8,000 species having already been collected in the United States, while several thousand species probably remain to be discovered, especially in our Territories west of the Mississippi.

On account of the ease with which the specimens are obtained and preserved, this is the favorite order of insects with collectors, and although not equalling in beauty the Lepidoptera, the gem-like lustre of many is not without merit, and above all the very distinct generic and specific differences leading to more accurate classification have induced many scientific men of high ability to devote their time assiduously to this order, and with the happiest results in philosophic generalizations.

The species are to be found in almost every variety of situation, among which may be here specified, under stones, especially where the soil is not very dry; under bark of dead trees in ants' nests; in fungi, on leaves of plants, especially on the low trees and shrubbery on the edges of forests and streams; in dead carcases of animals; in excrement. Many are seen flying and alighting again in roads during the hotter part of the day; some live in water, and can only be procured by small nets, while a great number of minute species may be taken on the wing just before sunset. Many are found only on the shores of the ocean, under material cast up by the waves; a large number will be attracted by a light near an open window at night. For the purpose of more easily securing these, the table on which the light is placed should be covered with a white cloth. Fi-

nally, many minute species will appear on throwing with the hand water on the damp mud of the banks of streams and lakes.

The most suitable times for collecting Coleoptera are the spring and autumn; during the great heats of July and August they diminish greatly in numbers; the search for them should begin as soon as the frost is out of the ground; at such times water beetles and those found in ants' nests, under bark, and under stones, are numerous.

COLLECTING INSTRUMENTS.

The collector of Coleoptera will require three nets: a large one, fourteen inches in diameter, made of thick white muslin, of strong construction, suitable for beating the bushes or for taking specimens on the wing, provided with a handle not more than fourteen or eighteen inches long; a smaller one, ten or twelve inches in diameter, also of strong construction, with a bag of millinet, suitable for raking up material from the bottom of ponds, streams, &c.; and a third, with a long handle, provided with a bag of gauze for catching cicindelæ, (the actively flying species seen in roads.) These nets are suitable for the collection of all insects, and their form and construction have been described under the directions given regarding other orders.

A very convenient bag may be made for beating bushes, &c., out of a bar hinged at two places, so as to form an isosceles triangle; the long legs serve as handles, and the bag of muslin may be fastened to the short leg and the bases of the long ones. An umbrella frame covered with white muslin also answers an excellent purpose.

Much may be done in the collection of minute Coleoptera by passing the material washed up by the waves of a lake or stream, or the earth of an ant's nest, through a sieve having not very fine meshes; the material passing through is received on a sheet of paper or a handkerchief, gently pressed, and then watched carefully for a few moments; the insects may be detected by the moving of particles, and can then be easily secured.

METHOD OF PRESERVING SPECIMENS.

A. *For Transportation.*

Coleoptera obtained on journeys, where economy of time and space is of importance, should be always placed in *strong* alcohol. The bottles to receive them should be small, not more than eight ounce bottles for large species, and one ounce or smaller for the minute ones. When the bottles are filled with specimens, the liquid should be poured off and replaced by strong alcohol; thus the specimens will be rendered firm and can be preserved indefinitely. *The colors do not change.*

If bottles are in danger of being broken, the specimens, after remaining for a day or two in alcohol, may be taken out, partially dried by exposure to the air, but not so as to be brittle, and then packed in layers in small boxes between soft paper; the boxes should then be carfully closed with gum paper or paste, so as to exclude all enemies.

B. *For Collections.*

Where the specimens are intended to be placed immediately in a cabinet, the smaller species should not be put in spirits, but rather in homœopathic vials, in each of which is a small piece of bibulous paper moistened with ether. Thus the specimens do not become wet, and can be gummed on cards without delay.

Pinning.—Coleopterous insects, more than one-tenth of an inch long, unless of very narrow form, should be pinned through the right elytron, in such manner that the pin passes out beneath, between the middle and posterior coxa of the right side; the pin must be graduated to the size of the specimen. German pins alone should be used; they are not so long and of harder and more elastic metal than the French, and much better pointed. Short English pins should always be avoided; they bring the specimen too close to the bottom of the box.

Insects less than a tenth of an inch long, or very narrow species of larger size, must be gummed on cards, which are placed on pins of No. 1 or No. 2. For economy in travelling, several cards may be placed on one pin, in which case the cards should be larger and put on No. 3 pins; they can afterwards be cut down to the proper size.

I have found the most convenient method of preparing cabinet specimens to be the following: Cut thin Bristol board into strips about one-fifth of an inch wide; from these, with sharp-pointed dissecting scissors, cut small isosceles triangles, in number equal to the specimens to be prepared; place each one on a pin about three-fourths of its height; then selecting the specimen to be prepared, arrange the feet and antennæ with two camel's hair pencils, or with one pencil and a pin; clip the end of the triangle so as to give a base about one-third or one-fourth of the length of the insect, holding the pin with the card in the left hand; touch the tip of the card with a pin dipped in the cement, then lifting the insect with a moistened pencil, place it at right angles to the altitude of the triangle and on the left hand of the pin; this position, if neatly given, and without any superfluity of cement, enables the under surface of the specimen to be very thoroughly examined.

The best cement is a mixture of inspissated ox gall, gum arabic, and water, and should be so thick that the specimen will remain in the position in which it is placed. Gum arabic alone is too brittle; the specimens prepared with it are apt to come off. Gum mixed with a little brown sugar answers very well; so does the common mucilage of the shops.

Setting.—The antennæ and feet of small specimens should be drawn out so as to enable them to be examined when necessary; of large specimens, they should be moved with brushes or fine forceps, with the same object in view. Any system of regular setting such as is adopted by English collectors of bringing the feet and antennæ as nearly as possible on a plane with the body is reprehensible; nothing can be more awkward than the appearance of a box of specimens thus prepared, and the specimens themselves are much more liable to injury. The posture should be as nearly as practicable that assumed by the

animal when moving, and the legs should therefore be in a somewhat depending position.

Cabinets.–The specimens should be preserved, either in drawers with tight covers in which are fitted panes of glass, or in boxes with very carefully fitting covers which lift off; boxes in the form of books are also used, but the cover being affixed to the box is in the way of the student. I have found that the best size for boxes required for constant study is 12 inches by $8\frac{1}{4}$ or 9 inches, (inside measurement;) the depth is to be proportioned to pins used, but one inch and a half clear of the cork, with which the bottom is lined, will be found ample. The boxes should be made of thin, well seasoned board, so that they will not become warped, lined with sheets of cork, such as used for boot soles, then neatly papered, and kept horizontally in a piece of furniture made for the purpose, the doors of which fit very closely by means of a tongue and groove running all around. Camphor should be kept always in abundance in the boxes or in the cabinet alongside of the boxes, and during the warm season every box should be looked at at least once in each month. The presence of infection is seen by the dust at the bottom of the pin bearing the infected specimen; this should at once be removed and dipped in alcohol or boiling water. Where it can be procured, *benzine* is the best material to use; it is to be applied with a pencil over the whole surface, and then the specimen is to be brushed with a clean pencil. Such preparation is considered in Paris to protect the specimen ever afterwards from infection.

I have tried various poisonous solutions, such as tinctures of strychnine, picrotoxine, piperine, &c., without avail. Arseniate of potassa will protect the specimens but injure the appearance very much.

When a specimen is badly gummed or pinned, it is to be thrown in boiling water for a short time, varying from half a minute to five minutes, depending on the size of the specimen, and the pin or card can then be removed, and the specimen repinned or reset on a clean card.

For the purpose of distinguishing specimens from different regions, little disks of variously colored paper may be used; they are easily made by a small punch, and should be kept in wooden pill boxes ready for use; at the same time a key to the colors, showing the regions embraced by each, should be made on the fly leaf of the catalogue of the collection, or in the Melsheimer catalogue, so as to be ever at hand for persons consulting the collection.

The specimens should all be pinned at the same height; the ease of recognizing species allied in characters is greatly increased by having them on the same level, and a general appearance of neatness is given which cannot otherwise be obtained.

It is better, even where numbers with reference to a catalogue are employed, that the name of each species should be written on a label attached to the first specimen. Thus the eye is familiarized with the association of the species and its name, memory is aided, and a greater power given of identifying species when the cabinet is not at hand.

No manual applicable to the Coleoptera of the United States has yet been prepared; such a work is much needed, as the student is now obliged either to seek in a large number of works the information he

desires, or to rely on his specimens being named by some person who has already mastered the difficulties of this bibliographical maze.

HYMENOPTERA.*

The Hymenoptera are insects furnished with *four membranous wings*, and which, in general, are capable of wounding by means of a *sting*, such as the wasps, hornets, bees, ichneumons, &c. They should be taken in a net or in pill boxes, but never more than a single insect should be put in one box.

They are found on flowers, bushes, and on walls, exposed to the sun or warmed declivities, in sandy places and in the earth. Their presence is often at once recognized by the existence of numerous holes in sandy places or in walls forming their habitations or the places where their young are deposited; all the *ants* belong to this order of insects. When an ant's nest has been found it is necessary to open it in order to secure a large number of individuals; in the interior, individuals with wings are found; these are the males and females, which it is very important to obtain.

The collector should secure the nests of Hymenoptera; they will be found fixed to the roofs of houses, in the holes of trees, pendent from branches, &c. The nests are often closed and have but one orifice; this may be frequently stopped up and the branch containing it cut off and secured with all its contents. When they are more fragile they should be carried in boxes, with which the collector should provide himself for this purpose, and protected by means of cotton or soft moss. It is very important to know what are the species which construct these nests, and it is therefore indispensable either to pin the insect and include the nest on the same pin, or fix the two on pins designated by the *same number*.

The collector should make a record of his observations, designating the individuals by numbers in case he is unacquainted with their names, and note the peculiarities of their habitations, their prey, their utility or their injurious qualities or habits, &c.

Hymenoptera should be set in the same manner as the Diptera, and should be killed by means of the *fumes of sulphur* or with chloroform. The legs should be placed in a natural position, and the tongue pushed forward so that this important organ, when present, as in bees, may be easily examined.

ORTHOPTERA.† (Linn.)

Earwigs, cockroaches, spectres or walking-sticks, praying-mantes, grasshoppers, katydids, crickets, &c., belong to this order; their habits are generally to feed upon vegetable matter of all kinds, and some of them, as the cockroaches, prey upon various materials of food in houses, &c.

Ear-wigs are mostly to be found, during the day time, concealed in

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* Furnished by Dr. B. Clemens.

† The paragraphs on Orthoptera, Hemiptera, and Neuroptera, have been furnished by P. R. Uhler, Esq., of Baltimore.

the corollas of flowers and between the leaf and stock of certain plants having no foot-stalks to their leaves; in the evening they are active, and may frequently be taken with a net, whilst flying, just before sunset.

Cockroaches of various kinds may be found beneath sticks, stones, rubbish, &c., and under the bark of decayed trees, mostly in damp situations.

Spectres or *walking-sticks* are to be found upon trees and shrubbery, and require very close searching to discover them, their color being generally so much like that of the bark or twigs of the trees they inhabit.

Praying-mantes are usually most abundant in gardens upon all sorts of vegetable matter, and, being large and conspicuous objects, may be readily seen and captured with the hands or net. Their time of appearing is from the middle of July to the end of summer.

Grasshoppers are abundant everywhere; some of the species fly very swiftly, and can only be obtained by following them with the net. The species are usually most numerous upon heaths, commons, and fields of grass. There are also a few kinds found jumping about near the margins of streams upon bare sandy places not covered by the water at high tide. These insects may be found during the whole year, but their numbers greatly increase as the warm weather comes on.

Katydids live upon trees and high shrubbery, and may be best collected by beating into an umbrella; this must be done quickly, however, as they very soon recover from the effects of their fall, and their long legs enable them to jump to great distances; their time of appearing is late in the summer or early part of autumn.

Crickets are found the whole year round under logs, sticks, and stones; their numbers are considerably increased by the early part of autumn, when they may be collected by sweeping from the grass, &c.

All the kinds of insects before enumerated may be placed in alcohol and suffered to remain in it for a considerable time without much change in their colors; it is very necessary, however, to have the bottles filled quite full in order to transport them; shaking about separates the parts, &c.

This order of insects may be collected during the entire year, but the best times are in the warm parts of spring and autumn; at these seasons their eggs are generally laid and the creatures arrive at their full state of perfection.

HEMIPTERA.

This order includes what are properly so called bugs, harvest flies, or cicadas, (improperly called locusts,) tree-hoppers, vine-hoppers, plant-lice, &c. The bugs are divided into terrestrial and aquatic. The terrestrial kinds are all found during the warm weather upon vegetable matter, and may be collected in all the ordinary ways, shaking into an umbrella, sweeping from the grass and low plants with a net, picking up with the hands, &c. The aquatic species can be obtained by fishing with a net amongst the mud at the bottom of ponds and streams and amongst water plants, and some are found

skimming over the surface of the water. There are also a few kinds to be obtained from the banks of streams in the sand and among the stones, under the bark of decayed trees, &c.

All the remaining insects of this order may be found on trees and plants, some living upon the leaves and others upon the trunk and stems; they may be captured by beating into an umbrella or sweeping with a net. Grape-vines will be found specially productive. Their time of appearance is during the warm weather, from the beginning of summer to the end of autumn.

NEUROPTERA.

Dragon Flies, Ephemeræ or May Flies, Lace-winged Flies, Ant Lions, White Ants, Caddis-worm Flies, (Phryganidæ,) Scorpion Flies, &c.—Dragon Flies inhabit the water in their first stages, and the perfect insect will be found most numerous in the vicinity of pools, marshes, and watery places. They are found only during the warm weather of spring and summer. The best method of collecting them is to station yourself close to the bushes, sticks, &c., upon which they settle, and wait till they alight, when the net may be thrown over them. A little practice, however, will enable you to capture them upon the wing, and by this means you will secure many rare species which could not be otherwise obtained. These insects had better not be placed in alcohol, as it will soon destroy their colors, and render them valueless; the best method yet discovered is to have little paper bags adapted to the size of the insects, into which they may be slipped after closing their wings against each other, and having wetted their bodies all over with alcohol by means of a camel's hair pencil, which, together with a small vial containing the alcohol, may be carried in the pocket.

The Agrionidæ, sometimes called Darning-needles, must be treated differently; it will not do to place them in papers; they must be pierced through with a pin and then stuck into the hat, a box, or something the collector must carry for the purpose. They are usually very abundant in meadows, near small brooks, ditches, &c., settling upon bushes and projecting objects.

Ephemeræ are generally best collected during the evening. The young of these and the Caddis-worm flies inhabit the water, and near it the imago will be found, sometimes in immense flocks, each one making a gyratory motion and flying with prodigious swiftness, usually around some adjacent tree. They must be collected with the net and pinned at once.

Lace-winged Flies are to be found upon trees, plants, &c., and, with the *Scorpion Flies*, may be beaten into the umbrella or swept into the net. All the remaining insects of this order, together with these two kinds of flies, must be pinned at once, and not placed in bags or alcohol.

Ant Lions will be found flying about near the margins of woods and in sandy places, near fences, &c. They are distinguished from the Dragon flies by the greater length of their antennæ, which always

have a knob at the end. They must be killed, like the Dragon flies, by applying alcohol with a brush.

White Ants will be found swarming in decayed logs, beneath stones, &c. They are very tender, and must be pinned at once. The insects of this order live during the warm weather only, and can be collected in the greatest numbers when the sun shines warmest and the days are fine. Many of them may be obtained by spreading a sheet in the woods or near some stream, among the bushes, during the night, and placing over it a bulls-eye lantern; the insects will be attracted by the light, and by means of the white sheet they can be more readily seen and taken with the net. This is also a most excellent method of *mothing* during the hot summer evenings.

INSTRUCTIONS FOR COLLECTING DIPTERA.

BY H. LOEW, WITH ADDITIONS BY R. OSTENSACKEN.

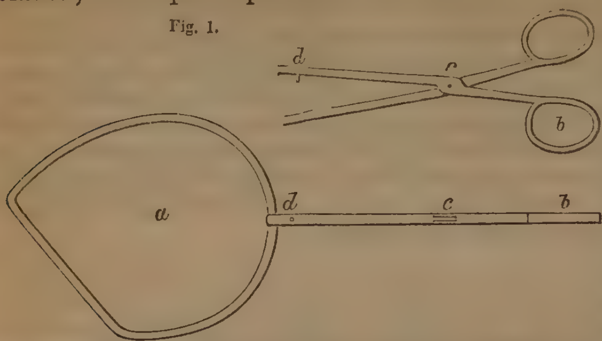
The first instrument I use in a locality, the fauna of which I am not well acquainted with, is a linen bag, fourteen inches in diameter and two and a half feet long, a little rounded at the top or apex, and attached to a strong iron ring, with a hollow metallic handle, in which, if necessary, a cane or other piece of wood may be inserted. With this bag I begin to sweep, and in a short time ascertain what insects abound in the grass, on the flowers, or in moist or dry places, &c. After the last sweep, by a dexterons twist of the handle I throw the apex of the sack over the ring, so as to prevent the escape of the insects, and give them time to compose themselves at the bottom. It is then opened, and I insert my head into it to see what I have captured. They immediately begin to move upwards. The common specimens I allow to pass; but if there is one which I desire to take, I let it advance to the middle of the bag, and then gently grasp it, from the outside of the bag, with the right hand. The other captives I drive down to the bottom by blowing moderately on them, and confine them there by letting the ring fall over the right hand, which holds the insect, which is now easily seized with the left hand. This operation is repeated until everything desirable is taken out, when the bag is emptied of its contents by inversion, and the sweeping recommenced.

This is the most important of all the implements used by the Dipterologist. Its employment prevents him from wasting his time in barren localities, promptly indicates the presence of rare species, and, by furnishing this information, enables him afterwards to have an abundance of specimens.

When I have, by the use of the bag, discovered the locality of rarities, I use another instrument, which is nothing more than an ordinary insect-forceps, of the form shown in fig. 1. Here, *b* is the place for the thumb, *c* is the joint placed near the handle in order that the

forceps may be closed rapidly; the remaining portion of the arms should be made so stout that they will not spring when closing the blades; *d* is a pin to prevent lateral motion when the blades are closed;

Fig. 1.



a the oval ring must be covered with a double cotton tape tightly sewed. If the forceps are not more than nine or ten inches long the ring need scarcely be bound with tape. Its angle and straight side are useful in capturing insects in particular situations. Then the space between the rings, on their internal side, must be covered with the best bobbinet, tightly drawn and securely sewed, so that a perfectly level surface be formed, in order to prevent the captured insect from struggling. The insect is pinned through the openings of the bobbinet, and is then easily transferred to the collecting box, or stuck into the sides or top of your hat, at pleasure. Two views of the instrument are given to illustrate its form more fully.

This instrument is not adapted for very small insects. For such, a forceps with finer bobbinet is used, but even this is superfluous, if you have become expert in employing the bag in sweeping, as well as in holding it under plants, bushes, and flowers, and, by gently striking or shaking them, allowing the insects to fall into it. Neither does it answer for the capture of very active species. It is, for the most part, useless to pursue such, and only betrays the intemperate zeal of the beginner. It is better to ascertain where such species pass the night, and thus you can easily capture that with your fingers which at other times would cost much labor. An excursion early in the morning, before the dew is off, is often very productive.

To carry more instruments with you than those just mentioned is an unnecessary burden.

Besides the capture, the *breeding* of Diptera, is of the greatest importance, and, for the most part, easy. The principal rule I follow, in order to secure the perfect insect, is, to be in no hurry about taking the imperfect one. If there is reason to presume that the larvæ will change into the pupa state at the place where it is found, I wait until then and gather the pupas. On a contrary presumption, I take the larvæ only when I observe that they are preparing for the pupa state. Decaying wood, mould in hollow trees, manure, and ground-earth under manure, stems of plants, grass, stalks of hollow weeds, dried flowers and their seed vessels, particularly of the *Compositæ,* furnish me the richest booty.

A bag full of the dried flowers of the *Compositæ*, or a bundle of dry burdocks and thistles, which I have had gathered for a few pennies, has always furnished me with something good. The pupæ of Diptera do

not require much care; only do not let the place in which they are kept be too warm. Those I wish to separate are put in large glass jars, the tops of which are covered with paper. The others I place in a wooden box, which I keep in an unheated room, on the window-sill. When they are developed from the pupa towards spring, they naturally fly to the window, from which I take them with a glass vial, or, what is better, with a small chip-box furnished with a glass bottom.

The third point of great importance is the preparation and pinning of the specimens for the cabinet. Sulphuric ether and chloroform are but inferior means of killing them. Specimens too long exposed to these agents are apt to spoil, and, if too little exposed to them, they revive. They answer only for certain tender minute species, of which I shall speak below. The best means of killing them are kreosote and the smoke of a strong cigar. The general rule is, to pin the flies whilst living, and thus to put them into the collecting box, which should have the bottom well moistened with kreosote, and be made tight. The captives will soon die, and thus, time after time, fresh subjects may be put in as they are caught. I have had boxes in which the largest Diptera were almost immediately killed, although the kreosote had not been renewed for six days, and which were still fatal to smaller species for six months afterwards. If you have no boxes thus prepared with kreosote, or, if you wish to avoid the odor of it, then prepare a box, so that, when it is full of pinned specimens, you may blow a few strong puffs of cigar-smoke into it, and all life will soon cease.

Fig. 2.

In the pinning of specimens, the long pins are greatly to be preferred to the short ones. Five-sixths of all the entomologists now use the long pins. *m n*, fig. 2, is the normal length of pins which are used for Diptera; the finer kinds may be of the length *m d*. The insects must be pushed high enough up the pin to enable the surface of its back to be examined with an ordinary lens without being incommoded by the pin's head. The back of the insect must, of course, be a little nearer the pin's head than the length of the focus of the glass. As smaller insects must be examined by glasses of higher power, they must be brought nearer the pin's head than larger ones.

Large flies may be pushed up so that their backs come to *b*, which smaller ones should reach *a*. Since the beautiful magnifiers of Oberhauser, which allow the application of a lower power, have come into use, insects may be pinned at a greater distance from the head, but not much greater.

The minute and tender species, such as the *smallest Cecidomyiæ*, *Campylonyzæ*, and others, must be treated differently. They cannot be pinned in the ordinary way with safety. Van Heyden has proposed the most rational and elegant method. The smaller species are caught by the linen bag, and are then put into very porous chip pill boxes, and are killed with cigar smoke, if boxes moistened with kreosote are not preferred. When twenty or thirty are captured the box is turned up so that specimens fall into the cover. They are then transfixed from below on fine silver wire, but not so as to allow the wire to project beyond the thorax. The silver wire must previously

be cut with ordinary scissors into pieces of proper length and taken with you. The wire must be inserted into the insect by means of a very delicate pincers, and with the same instrument the other end of the wire must be stuck into a box, the bottom of which is covered smoothly with the pith of plants. Over the pith thin paper may be fastened in order to render the surface still more smooth. The top or cover of the pill box, in which the insects are placed while transfixing them, must not be too shallow, so that they may not be blown away by the wind, if the operation is performed in the field. The use of a glass vial for the capture of small insects is not to be recommend, as the moisture separates their parts and thus spoils them. The vial may be used on excursions, when you desire to take home a single living insect for the purpose of examining the organs of its mouth or its internal structure.

Those specimens which have been transfixed on the silver wire, as above indicated, are prepared for the collection in the following way: In the fall, stalks of weeds with pith not too porous, and before it is quite dry, must be collected. The best adapted for this purpose is the pith of *Artemisia*, and, still better, of *Verbascum*, (mullein.) It is cut into small

Fig. 3.

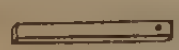


Fig. 4.

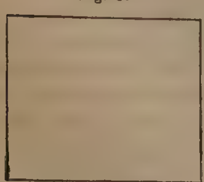
pieces, which, seen from above, have the form and size of fig. 3, and seen from the side the thickness of fig. 4. Then insect pins of moderate size are inserted through these

Fig. 5.

small pieces at the place indicated by the dot, (fig. 5,) and the pieces are pushed up nearly to the pin's head. As the pith is still moist it will adhere to the pin in drying, and by the slight coat of verdigris which will soon be developed, the insects, which have been previously attached to the silver wire are now inserted on the free end of the pith with the delicate pincers, where they will stick fast enough if the proper kind of pith has been used. Pith of *Sambucus*, or elder, *Helianthus*, or sunflower, and similar plants, do not answer the purpose, because it is too porous. The insect should stand a little higher than the head of the pin, so that it may be conveniently examined from all sides. The silver wire used for this purpose should be of the very best quality so as to prevent the development of verdigris.

In regard to the *Tipularia*, and some others, whose legs easily break off, my method is the following: I capture them with the forceps and pin them as other large specimens. Before pinning, I press the thorax, so as to prevent all struggling; I then stick the pin through a piece

Fig. 6.

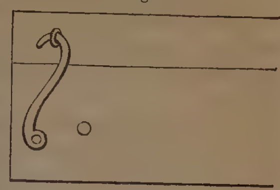


of paper of this form, (fig. 6,) and push it up far enough to receive the legs of the insect neatly spread out or turned under it. When the insect is dead I remove the paper, which, however, might as well be suffered to remain.

The boxes in which Diptera are kept should be about a foot square, the top should be glass, and made to fit tight to the other part by a double rab-

bet. Some persons, in addition, fasten the cover down by means of brass hooks, to prevent warping, (fig. 7.) The boxes may be made of any well seasoned wood. The bottom of the boxes should be made of wood cut *horizontally* from the trunk in plates one-fourth to one-third of an inch thick, and in this case we may use the harder kinds of wood from deciduous leaved trees, except when the rings making the last growth of the year are very hard, or else a very soft wood may be used, such as the partially decayed wood of dead linden or poplar trees; but the pieces are cut out lengthwise in the ordinary way. In both cases the finest pins can be easily inserted into the wood without risk of injuring their points and hold very well. But in the latter mentioned kind of bottom a fine pin readily takes a wrong direction, and after having been taken out it is difficult to insert it again in a perpendicular position. The use of soft material for lining the bottom of the boxes has been generally abandoned in the best collections. It is only when *perfectly* tight boxes cannot be procured that the lining is used, and then not so much with reference to the insertion of the pin as to facilitate the poisoning of the box and to exclude the *acari*, psoci, and other insects. The best material for this purpose is blotting paper spread over with mercurial ointment, and over this is laid a fine oiled silk of light color. The oiled silk may be faintly ruled with cross lines to facilitate the symmetrical arrangements of the specimens. If the oiled silk is fine enough it offers no perceptible resistance to the finest pin. But a more serious inconvenience is, that it prevents us from seeing the texture of the wood at the place where the pin is to be inserted, and hence the points of the very fine pins are liable to injury. On this account it is much better to use wooden boxes without any lining, and these when neatly made look well enough. But if it is deemed desirable to still further improve the appearance of the boxes, a sheet of thin paper may be spread over the bottom, provided the texture of the wood is very uniform or very fine pins are not to be used. This paper may be renewed from time to time, and should be fastened by glue and not by paste, which only furnishes a bait for destructive insects.

Fig. 7.



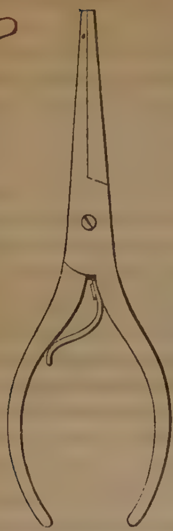
If it is deemed advisable to poison the boxes, it is most conveniently done by means of bits of felt smeared with mercurial ointment, which are fastened in the covers. During the examination of the insects the covers may be set aside, if any injury to the health is apprehended; but of this there is not the slightest danger.

In securing the insects in the collection there is one indispensable rule: nothing should touch the bottom. The labels of genera and species, as well as those on the pin, with each specimen, should be as high as possible; the first being nearly on a level in the specimen.

The labels are best made of stout paper, as they are then better kept in position on pins of moderate thickness.

Fig. 9.

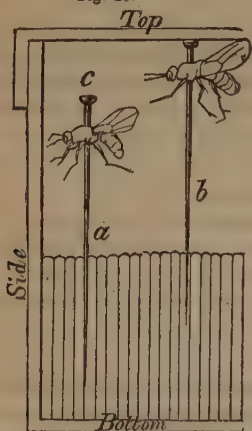
Fig. 8.



The specimens should be placed at such a distance from each other that they may conveniently, and without risk, be removed and replaced—an operation which is performed with a steel pincers, having the shape indicated in the figure, (fig. 8.) The handle should be large enough to allow a firm grasp of the hand, and the branches should be kept constantly a little separated by means of a spring, as represented. The jaws of the pincers should be roughened like a file on the inside at the ends, and they may be either straight, or, still better, slightly curved, (fig. 9,) as in the figure, to admit of being passed more readily beneath the insect.

The cases used on excursions, or entomological trips, are differently constructed from those of the cabinet. The bottom must be lined with a material soft enough to allow every pin, even the finest, to be inserted easily without the aid of pincers. The best material for this end is pasteboard, which is cut in narrow strips glued against each other, so as to be in a position perpendicular to the bottom of the box.

Fig. 10.



The bottom of the box is lined with these strips, so that the pins move between the layers of the pasteboard. To prevent the pins so loosely inserted from dropping out, the lining should be sufficiently thick, and, at the same time, the box low enough to allow the head of the loosening pin to lean against the cover before dropping. (See fig. 10.)

Note by R. Ostensacken.—Collectors of Diptera should always endeavor to obtain *both sexes* of every species. The sexes in the families of the *Tipulidae* and of the *Asilidae* (for the greater part) are easily distinguished by the form of the abdomen, which is generally club-shaped or obtuse in the male, and more or less pointed in the female. In other families (*Tabani*, *Syrphi*, *Stratiomydae*, *Bombylii*, and in most of the true *Muscidae*) the eyes are close together in the male, and separated by the "front" in the female. Sometimes they are separated in both sexes, but then the front of the male is generally narrower than that of the female. If these characters fail to help in distinguishing the sexes, the size, and especially the shape, of the abdomen will be sufficient. The males are, for the most part, smaller than the females, and have the abdomen more slender.

It often happens that one of the sexes appears in great abundance, while not a single specimen of the other can be seen. In such cases

the following observations of Dr. Schiener (Wiener Entomol. Monatschrift, 1858, p. 175) may prove useful:

"From manifold and repeated experience I have arrived at the conclusion that whenever one sex of a Dipterous insect appears in great numbers, the other is always to be found somewhere in the immediate neighborhood.

"If the males soar in the air we can generally predict with certainty that the females are not far off quietly reposing on trunks of trees, as is the case with the *Anthomyzidæ*, or on the under side of leaves, as with the *Syrphidæ*.

"If every indication of the resting place fails, I then commence catching everything living and flying in the immediate vicinity, sweeping in the air and shaking or beating the leaves and grass, and in this way I have generally succeeded in obtaining, among one hundred specimens of the one sex, at least one of the other.

"The males soaring on the tops of mountains are generally isolated, but on descending several hundred feet we will seldom look in vain for the other sex resting on leaves or the heads of umbelliferous plants.

"I have even succeeded, by patient perseverance, in discovering single males among the numerous female horse-flies (*Tabani*) which attack cattle."

Those who wish more detailed information about the localities where rare species of Diptera have to be looked for will find them in Bremi's excellent paper on this subject, (Isis, 1846, p. 163,) as well as in an article of Mr. Hoffmeister, in the "Entomologische Zeitung" of Stettin, 1844, p. 360.

INSTRUCTIONS FOR COLLECTING LEPIDOPTERA.

BY BRACKINRIDGE CLEMENS, M. D.

This order of insects includes the butterflies, sphinges, and moths, and is divided by systematists into two very distinct and easily recognised sections.

The members of the first are known as diurnal Lepidoptera, or *Rhopalocera*, and are characterized by possessing *antennæ that are always club-shaped at the extremity, by their diurnal flight, and the wings being held elevated during repose.* They are commonly designated butterflies, and their diurnal habits and beauty render them familiar objects to the most casual observer. Their natural history, also, is much better known than that of the members of the second great group under this order, the great majority of those belonging to the United States having been described in Boisduval and Leconte's Iconographie des Lepidoptéres de l'Amerique Septentrionale, and in the works of the older entomologists, Cramer, Drury, &c. There are, however, doubtless, many species still undescribed, but the writer wishes to direct special attention to the individuals of the following group, which, being far more unfrequently the objects of attention,

are but little known, and it is particularly to them that the following instructions must be understood to apply, while at the same time they are applicable to the diurnal species.

The second section, to which the attention of students and observers is specially called, is composed of the *sphinges*, or *hawk-moths*, and *millers* or *moths*, and known as *Heterocera. Their antennæ are of various forms, and never club-shaped at the extremity; their flight is usually nocturnal, and their wings, in repose, with a few exceptions, are flat.* The merest novice in entomology, by keeping in mind these marks of distinction, can have no difficulty in recognizing the members of these two great groups. The nocturnal lepidoptera or heterocera differ greatly in size, some being very large and beautiful; others, again, are small, even minute, and their colors frequently sombre and dull; but it is hoped that none will be neglected on account of this diminutive size or unattractive appearance. When, however, the specimens are minute a certain degree of manipulative delicacy, acquired by practice, is requisite either to pin them successfully or to set the wings subsequently. For this purpose small pins, manufactured especially for this use, may be procured. Those made in London are preferable either to the German or French.

HOW TO COLLECT LEPIDOPTERA.

The body and wings of lepidoptera are covered by minute scales, which are attached by a slender stalk to the external surface. They are easily detached from their connections, and it is very important that the collector should avoid, as much as possible, denuding the surface whilst taking specimens, or manipulating them after their capture. Badly denuded specimens are quite worthless, because, when the peculiar markings or ornamentation of the wings are effaced or injured, they are not attractive objects for the cabinet, and if new, a good specific description cannot be made from them. This caution should attract, therefore, the particular attention of every one who undertakes to collect. *Moths should never be taken by the wings with the fingers.* If no other means of securing them is at hand, it is far better to permit them to enjoy their life and liberty than to endeavor to make specimens of what would be only an incumbrance to any collection. When it is necessary to seize them, either for the purpose of pinning or to cripple them after capture, it must be done according to a prescribed mode, in the application of which the specimen is subjected to the least possible injury. In order to accomplish this the insect is seized firmly with the thumb and forefinger by the sides of the thorax, *beneath the wings*, or, rather, in such a manner as to elevate them and hold them immovable. The pressure is applied at the base of the wings, and must be firm and steady, for the insect is able to make strong resistance with the muscles of the thorax, and is liable to escape.

It would, perhaps, be proper to mention here that two divisions of lepidoptera are frequently mentioned by name in entomological works, the one as *macro-lepidoptera*, including the rhopalocera, sphinges, bombyces, geometrides, and noctuides; the other as *micro-lepidoptera*

which is composed of the pyrolides, tortrices, tineides, oterophorides, and alucitides. Some of the macro-lepidoptera, however, are of small size, whilst, on the other hand, many of the "*micros*" are comparatively large; but there is a certain convenience in the use of the terms, as standards of comparative size, which renders their occurrence quite frequent.

The implement most used in capturing lepidoptera is the *ring-net,* made as will be hereafter described. By means of this they are taken on the wing, and as they hover over or after having alighted on flowers, leaves, &c. The requisite dexterity in using it efficiently is soon acquired by practice, and a little experience respecting the habits and mode of the flight of the objects sought. When the insect is once within the net it can be kept quiet and at the bottom, by keeping it in motion from side to side, so as to permit the air to rush through its open end. But how can the specimen be secured with the least amount of injury? There are several ways by which this can be accomplished. When the specimen is of large size the net should be seized with the left hand in such a manner as to prevent fluttering as much as possible, and to guard against its pushing itself into the folds; and it is then seized by the thorax with the thumb and forefinger of the right hand in the manner heretofore described, and smartly squeezed so as to crush it and thus deprive it of life; or it may be touched *on the head* through the net with the glass stopper of a bottle containing *chloroform;* the bottle having been shaken previously to removing the stopper it will carry enough to benumb completely the largest moth after two or three successive applications. I much prefer this to compression of the thorax, although the insect usually revives, but this can be prevented after pinning by using some one of the poisons to be hereafter mentioned. The effect of chloroform applied thus is almost instantaneously to quiet the most violent flutterer, nor is it necessary that any other portion of the insect than the head should be wetted by it.

When the captive is a "micro," it may be prevented from escaping by blowing a vigorous stream of breath on it through the open end of the net; but if it proves to be too strong to be kept down thus, the net must be immediately put in motion again to prevent its escape, turning the open end alternately from one side to the other. After throwing the specimen well in the apex by this means, my own mode of operation is to grasp it with the left hand, taking care to have the thumb and first finger upward, just above the specimen, and thus close the net. Then by elevating the hand through the ring or on a level with it, a *common cupping glass* of about two inches diameter, or a *wine glass,* carried in the pocket, is placed on the top of the left hand over the constricted portion, the grasp relaxed, and the insect permitted to escape through the opening into its interior. The glass is then closed below by the left hand on the outside of the net, and may be transferred to the top of the collecting box, where it can be quieted with chloroform and pinned. All lepidoptera, except those of large size, can be easily secured thus, and without in the least stripping any portion of the body of its scales. The smaller tortrices and tineae, which can be kept within the net by blowing, may be likewise secured by the glass, which is placed over them as they sit on or ascend the sides of

the net, and I much prefer it to the ordinary mode of securing them in *pill boxes*. The English entomologists all use the pill box, I believe, to secure a micro after it is within the net, but it involves the necessity of carrying a great many of them in the pockets, and the trouble of killing one's captures after returning from the field wearied with exercise. Therefore I much prefer to kill and pin on the field, although to accomplish the latter satisfactorily often requires, in consequence of the minuteness of the objects, a steady hand.

When walking over grassy meadows or amongst low herbage I am in the habit of using the net by *sweeping*, and to very great advantage. This operation is performed by giving the net an alternate right and left motion as the collector walks forward, keeping the open end inclined at about an angle of 45° to the plane of the surface, touching with the lower part of the ring the tops of the grass and herbage, and as the net distends itself with air, being careful that the apex does not drag or strike when it is turned at the extreme right and left points of the sweep. The motion should be gentle and continuous, and the mouth of the net merely reversed in the alternation, so that the apex is kept constantly flying in the air and free from contact with any surrounding bodies. By this means he secures everything that rises as he advances, and after every half dozen sweeps the net is brought to the face, and a stream of breath blown into it whilst the collector inspects the interior. Should it contain anything he desires, it may be selected, or even a half a dozen "micros" secured one after the other by means of his glass, and all brought at the same time to the top of his collecting box in the most perfect condition. In this manner I have often collected 150 specimens during a few hours' walk in the afternoon and evening. The operation may not be made very comprehensible by description, but a few endeavors to practice it, will soon put the collector in possession of the art. Of course, sweeping is inapplicable when the grass and herbage are wet with dew.

In addition to these means of collecting, the "micros" may be taken in *pill boxes* wherever they may be seen, should the net not be at hand, and the collector will find it advantageous always to carry a few in his pocket during the entire collecting season.

The *wide-mouthed bottle*, presently to be referred to, forms an excellent collecting agent in the field, or to capture those which are attracted to our rooms by light during the nights of summer. Or the *cupping-glass* or *wine-glass* will enable one to secure many exquisite specimens in the field during the hot, sultry days of June and July, when they will be found on the leaves of the herbage of the cool, shady wood, gamboling over their surfaces like veritable elves, or so immovable that they seem to be enjoying an afternoon siesta, or feasting on odorous wild flowers. In using the glass for this purpose, the object must be gently approached so as not to alarm it, and the glass cautiously advanced until it is just over the spot occupied by the specimen, whilst the left hand is advanced beneath; the glass is then brought down rapidly over the object upon the left hand which closes it, and if you have struck skilfully, secures you perhaps a rare species in all its original beauty.

The collector will soon ascertain what are the most productive

localities in his neighborhood, and where particular species are to be had in greatest abundance. When these are once ascertained, let him learn to hunt quietly, and endeavor to bring into exercise his powers of observation; never moving until he has scanned every leaf and object around him, noting the habits of the little people of the great unknown world by which he is surrounded, their peculiar mode of flight and concealing themselves, and the situations which appear most agreeable to them. His net should always be in readiness to secure everything which his motions and footsteps may startle, but should he fail, let him not, to the infinite alarm of the minute inhabitants of the forest, rush headlong after it through brambles, herbage, and grass, and over the decayed trunks of trees, striking frantically this way and that, until he glows with a heat above the summer point, and is bathed in perspiration and fairly disgusted with Entomology, which involves so many discomforts. Let him rather be self-possessed and cool, mark where the coveted object alights, and he can easily secure it without affecting the steadiness of his nerves, and perhaps rendering the specimen worthless subsequently, during the operation of pinning. This, of course, is advice to the incipient collector.

The nocturnal Lepidoptera may be taken by stratagem as well as by *coup de main*. Prominent among the expedients used for this purpose are what is called SUGARING, and the use of LIGHT.

To obtain moths by means of the former, a mixture of *coarse brown sugar* and *ale*, with the addition of *a little rum*, should be made. The mixture should have the consistence of treacle. The collector, with an assistant, should take his mixture to the wood about sunset, *or a little before or after*, and daub it on the trunks of the trees by means of a brush, or saturate strips of cotton cloth with it and tack them to the trunks. As soon as it gets dusk the sugared places should be revisited, and the light from a bull's-eye lantern thrown on the sugared spots. For several hours the moths will continue to arrive, sometimes in considerable numbers, and may be taken with the net, which should be held beneath the sugared spot previously to turning on the light, as many have the trick of *falling;* or captured, as they sit feeding on the dainty bait, by means of a wide-mouthed bottle having ammonia or chloroform on cotton or a sponge on the bottom. The *noctuae* are principally obtained by this means, and one or two expeditions should be made every week during the collecting season, viz: from early spring until the latter part of autumn, avoiding localities where odorous flowers are plentiful. The collector should not be discouraged if troops of moths do not come at his first invitation, or even if he should be compelled to return home rich in patience but very poor in specimens.

The fascination of the "foolish moth" by *light* has a time-honored use, having served to adorn many a tale and point many a moral; and yet there is beneath the fact a hidden meaning or moral, perhaps, unsuspected by either poet or moralist. It is sufficient for the collector to know they are fire-worshippers, and to avail himself of this tendency to secure their fleeting forms in their season. This may be done by taking a lantern into the open country near a wood, and suspending it over a white sheet spread on the ground, thus showing their forms

more distinctly, when they may be captured with the net. But this expedient is very far inferior to *sugaring*.

Many specimens can be taken with but little trouble by placing a light within a room on the ground floor before a closed window, particularly one facing a garden or the open country. The moths will flutter on the outside before the light, or alight on the panes of glass, when they can be easily secured in pill boxes, killed and pinned as they are caught. Moonlight nights are unfavorable to the use of light.

Those who live in towns lighted by gas will be able to secure many specimens around the lamps; or by making friends with the lamplighter and supplying him with pill boxes, he may furnish you every morning with many specimens and sometimes rarities. In using the light for making captures, care should be taken to guard against the moth singeing its antennae or wings in the flame.

The males of the Bombyces chiefly may be taken by exposing the *virgin females* with crumpled wings on trees, or enclosed in cages, exposed in the open country.

I would earnestly recommend every collector to note the date of capture of all his Lepidoptera on a little square of paper, and pass the pin transfixing the insect through it. It is simply necessary to indicate the month by its initial letter and to give the day in figures. By following this plan, which will indicate approximately the earliest and latest periods of their appearance, and the numbers of broods during the season, he will be able to tell at any time when to look for the species he may desire, and to form a calendar showing the periods of appearance of species, and will enable one to make accurate comparisons in this respect between widely separated geographical areas. Many species of our lepidopterous insects are spread over immense areas, and some of them appear to be common to the entire continent, and a calendar of this kind, when once formed, would show the successive pulsations of lepidopterous life, (as it advances along the broad sun-track from the genial regions of the Gulf to our northern boundaries, and throbs over the great western plains to the Rocky mountains.)

HOW TO KILL LEPIDOPTERA.

Insects should be killed with at least some manifestation of humanity, so as not to engender a spirit of cruelty in the minds of the young who may witness the operation, and it should be accomplished, at the same time, with poisons or agents that can be trusted in the hands of the young and those inexperienced in their effects. A great variety of agents have been recommended for this purpose, and it would be quite unnecessary to allude to all of them.

Chloroform is exceedingly useful to the collector, in consequence of the rapidity of its effects. It is objectionable, however, inasmuch if its influence is carried too far it causes rigid contraction of the thoracic muscles, which throws the wings into positions that renders setting them subsequently almost impossible. Moths should therefore merely be benumbed by it. A few seconds is sufficient generally to produce this effect, and the influence of the agent intermitted for the purpose of pinning the insect. When this has been done, if it is

of large size, its revival may be prevented by using oxalic acid, as will be presently explained; or if a "micro," the pin containing the specimen should be fixed in a piece of cork and introduced into the ammonia bottle. When using chloroform for benumbing the very small moths, care must be taken that they do not fall or introduce themselves into the drop used for this purpose; for it ruins them irretrievably; therefore it should be spread by passing the glass which contains the specimen over it; or, what is perhaps better, the top of the collecting-box, (since it is in the field that this accident most frequently occurs, (should be covered with dark colored cloth glued to the surface, and this will absorb the liquid sufficiently to prevent its occurrence. The collector should not, then, kill the smaller moths in the field with this agent, but permit them to revive, and kill and set them after returning home. It should never be applied to a *varnished* surface, for it is a solvent of all varnishes.

I would recommend this agent, then, to be used as the means of abolishing the power of voluntary motion in moths, thus giving the collector plenty of time during which he may pin them without struggles or efforts to escape on their part.

Oxalic acid is employed to kill large moths after they have been pinned, and should be in the form of a *strong water* or *alcoholic solution.* In using it a steel pen, or a quill pointed like a pen, but without the slit, should be dipped in the solution and passed into the side of the thorax *under* the wings. The pen should be held there for a short time and moved from side to side so that the whole of the solution may enter the body. In killing large females it is best to make more than one application. The objection to the acid is, that it leaves a white spot, which is apt to spread and disfigure the specimen, but this can generally with care be obviated. It is possibly scarcely necessary to state that it is a *violent poison* when taken internally, and that the bottle containing it should be the object of some care.

Ammonia is an excellent agent for killing Lepidoptera; the *strong spirits of ammonia* should be used. In order to make use of it a wide-mouthed, moderately deep glass jar should be obtained, and the edges of the mouth ground down accurately on a piece of sheet lead with emery and water, so as to allow a piece of heavy plate glass to close it air-tight. If the jar rises in the centre, the bottom may be filled with cotton so as to obtain a level surface. When the jar is to be used, a piece of sponge is wet with a few drops of the ammonia, (the operator should have some care for his fingers and nose at the same time,) and the insect introduced, either pinned to a piece of cork or free as the operator pleases. They soon become motionless, whatever be their size, but will revive if taken out at once; *a half an hour* is sufficient to prevent the revival of the largest moths, but they may remain without injury 24 or even 48 hours, perfectly relaxed and fit for setting any time during that period, in consequence of the moisture within the jar. The small Lepidoptera, tortrices and tineae, taken in pill boxes, may be killed by placing the lid *aslant* previously to introducing the box into the jar. The smallest kinds, the leaf miners, nepticula and lithocalletis, should be pinned and set out immediately they are dead. *Green moths* have their color affected by ammonia.

The *carbonate of ammonia* is recommended as a substitute for the spirits, in consequence of no vapor collecting in the bottles, and being cheaper and safer in the hands of the young. The best way to use it is first to reduce it to small pieces, (not powder,) and to enclose it in a small bag made of any porous material, and place it with its contents at the bottom of the bottle, covering it with a perforated card.

HOW TO PIN LEPIDOPTERA.

In the first place, the pin should be adapted as far as possible to the size of the specimen. The pins in use amongst the German and French entomologists are too long and slender, and are liable to bend in thrusting them into the cork unless carefully used. In these respects the English pin is much to be preferred; that used for the "micros" being only three quarters of an inch long. The common pin, about $1\frac{1}{4}$ inch long, answers very well for the large moths, and the size somewhat short of an inch will do for those of moderate size; but for the micros it is *indispensable* to have a supply of Nos. 10, 19, and 20 of the English make. They are manufactured by Messrs. Edleston & Williams, Crown Court, Cheapside, London.

The pin should be thrust vertically through the body in the centre of the *thorax*, or the part to which the wings are attached. After it has fairly entered the thorax a piece of soft cork is used, by pushing the point of the pin into it, to raise the specimen the requisite distance up the pin. At least *one half* of the pin should be exposed below, and uniformity in this respect can be obtained by always using the same thickness of cork for this purpose. When about to pin a specimen it should be placed on a cloth-covered surface to prevent it slipping about, and if, under the effect of chloroform, it has turned on its back, be reversed with a pin; or those of moderate or large size may be taken by the thorax and feet with the thumb and finger of the left hand and pinned whilst being thus held, and the position of the specimen afterwards regulated by the cork. Specimens can be easily transfixed on the top of the collecting box, if it is covered with cloth, without the necessity of touching them with the fingers. Many of the micro Lepidoptera, however, turn upon their backs and project their posterior legs; if they cannot be easily reversed again with a pin, they must be taken between the thumb and forefinger of the left hand, *by their projecting legs*, and permitted to fall in the space formed by the contact of these members, with the *head to the left or front* according to the position of the hand. Then, by taking a small pin between the thumb and forefinger of the right hand, and resting the unoccupied fingers on those of the left, in order to insure steadiness, the pin is easily pushed through the thorax of even the smallest species. The success attending this operation depends on taking up the specimen so that it will rest closely in the sulcus of the thumb and forefinger, with the head well forward. Of course, previously to taking it up, the head should be turned to the right. A few failures in the first instance should not discourage the beginner.

HOW TO SET LEPIDOPTERA.

The wings of lepidoptera are usually *set*, that is, expanded as though in the act of flying; but it is well to have one or two specimens showing the wings in their *natural position* during repose. The collector should prepare, in the first place, a number of braces of stiff card, varying in length from half an inch to two inches, cut so as to taper towards one end, square at the other, and about the fourth of an inch broad. Through the broad end of each, a large strong pin should be introduced. A piece of board should then be covered with sheet cork glued to the surface; this forms what is called the setting board. When a specimen is to be set, two of the braces are fixed on the board at a sufficient distance apart to receive the body between them, and to support the wings well after expansion. Then, with a setting needle, a common needle thrust into a piece of wood so that it can be used more conveniently, the wings are expanded on the lower braces and fixed there by placing over them additional ones. Another form of setting board is made by having grooves in it to receive the body and then by applying braces to the expanded wings they are easily retained perfectly flat. Some use pieces of plate glass of different widths to press down the expanded wings, but it is not the best plan, strips of paper pinned over the wings being preferable.

The wings should be expanded by introducing the setting needle on their *inner margin*, or where they meet over the top of the body. Insects should be left on the board from a day or two to four or five, according to size and the condition of the weather. Care must be taken to exclude mites from the board; this can be done by using a mixture of equal parts of *oil of thyme*, *oil of anise*, and *spirits of wine*. It should be spread over the setting board, and especially laid on the grooves, and for this purpose *spirits of turpentine* is also very effectual and much cheaper than the mixture of essential oils.

REARING THE CATERPILLAR.—THE VIVARIUM.

The study of Lepidoptera does not consist in the collection of perfect insects and the investigation of their peculiarities of structure. They have all lived an active, voracious, and interesting life previously to transformation from the embryonic state to that of maturity, and it is the aim of the naturalist, as well as of natural history, to look kindly into their individual existences, and seizing the particulars of each little life by observation, to write their biographies. The student must free his mind from the worship of the idols of size and physical beauty, which incline him to regard with respect him who devotes his powers to the study of mammals, whilst he smiles pityingly on one who falls into ecstacies over a new found beetle. Wherein is the superiority of the former pursuit? The same evidences of thought are discernible here as there, adaptations more wonderful, habits more interesting and more injurious to our interests, an anatomy more complicated, physiological questions more difficult of solution, and even life itself seems to laugh at regularity or harmony

among the insect world in its manifestations of strange, wonderful, ridiculous forms, and their mode of ornamentation and clothing. But here, as elsewhere in the animated world, we have expressed in vital characters the thoughts and conceptions of a living God.

It is imperatively necessary to entomological science that the habits and transformations of larvae should be studied and known, and their forms and ornamentation well described. The study possesses these advantages over most other departments of natural history, that it can be pursued during leisure and unoccupied time, its inexpensiveness, and the abundance of the objects to be observed. In the trust that many into whose hands these instructions will fall may become observers and students of Lepidoptera, and being conscious that to the novice everything in this connexion is of value, the attempt will be made to anticipate much that may embarrass him.

Those who delight to ramble in forests and green fields during the genial days of spring and the cool mornings of summer for "air and exercise," little know how much pleasure and profit result from such rambles when undertaken with some definite object in view. Things which were before unmeaning or unquestioned become the subjects of inquiry and information when that object is connected with natural history, and every field and hill side, every shrub and plant becomes the theatre of startling scenes of life and death, of artifices and devices more incredible and wonderful than the most fanciful creations of fairy lore. With observation thus kept constantly on the alert, the student will have but little difficulty in finding the objects he seeks; but we will help him by pointing out such indications of the presence of larvae as may at first escape his attention. The early morning is the most favorable time to seek for the caterpillar, which seems to prefer its food moistened with dew, although they may be found during any other portion of the day. When they cannot be at once seen, their presence is indicated by finding their "frass" or ejectamenta beneath the plants on which they feed; by partly eaten leaves, or leaves contorted and rolled into cylinders and cornets and secured by bands of silk, or superimposed and bound together in the same manner; by the existence of a hole surrounded with "frass" in the pithy stalks of various plants, or in subcortical mines near the roots of various trees and shrubs; in the stems and leaves of various grasses, or living in portable cases on the leaves of plants, or within houses, feeding on various articles of food and apparel; or by the existence of *discolored patches* on the surface of the leaves of various plants and forest trees, the oaks, the linden, the beech, the iron wood, the elms, the hickories, the sycamore, &c , caused by minute leaf mining caterpillars freeing the epidermis in the process of feeding on the parenchyma, or feeding on grains and the seed heads of composite plants, on lichens and fungi. Besides the lepidopterous leaf miners there are *coleopterous* and *dipterous* miners, which are rather difficult to distinguish from the former; in general, however, the dipterous larvae are more maggot-like in appearance, and the coleopterous leaf miners, in many instances, stain the whole surface of their mines with their "frass," which appears to have been dissolved, whilst that of the lepidopterous larvae is in little pellets. There is, how-

ever, no certain mode of distinguishing but by experience, for the oldest collectors are sometimes deceived. Many caterpillars hybernate during winter, and may be found concealed under stones, &c. when the cold weather of autumn approaches, or are dug up at the roots of trees during search for pupæ. They should never be kept in a warmed room, but exposed as soon as taken to the temperature of the external atmosphere. And lastly, we must not forget to mention that a number of species inhabit the water plants, growing in quiet pools and on the margins of little lakes.

With regard to the means of collecting specimens, the student should supply himself with a number of pill-boxes of various sizes, in which to carry his captures when found, remembering that some of them are carnivorous, and will make a meal of their companions when forced into intimate association. He must note particularly the plant on which the larva has been found, and put a portion of it in the box, and remember that in general they will eat of nothing *but the species of plant on which they were found.* Hence it is almost impossible to rear a larva which has been met with under conditions that give us no information respecting its natural food plant, unless by trying it with a variety we at last accidentally find one it will eat.

He should carry an umbrella, and by beating bushes and the branches of trees into it with a cane or rod, it will receive the dislodged larvae, and save him the trouble of search. Or several yards of white cotton sheeting may be spread beneath a tree, and the upper branches above it beaten with a pole, when we have reason to suspect the presence of larvae. An ardent collector, living in a little village in this vicinity, carries with him during his excursions a stout rope and hatchet. If, in examining the ground beneath forest trees, he finds fresh "frass" from the larger caterpillars, he scans the branches until he detects the eaten leaves, and then, casting his rope over a stout limb by means of a stone, he ascends the tree rapidly, severs with his hatchet the branch on which he supposes the larvae to be, and, descending, secures his well-earned prize. In this manner he has frequently collected on the hickory during one day twenty larvae of the rare and beautiful *Dryocampa imperialis.*

When leaves are unrolled to ascertain if a larva is present, it should always be done over a spread handkerchief, as otherwise the disturbed inhabitant may make its escape by falling to the ground. All falling larvae, however, attach their thread previously to deserting their food plant, and can usually be found, if they have reached the ground, by passing the hand beneath the place where it was, when it will come in contact with the thread, and this will serve as a guide to find it again. The mines of leaf miners should not be opened to ascertain whether they contain an inhabitant; this information can be obtained by holding the leaf between the light and the eye.

The collector will sometimes find the *egg* of some species of ichneumon attached to the skin of the larvae. We do not mean the cocoon of the larva of a small ichneumon, so frequently mistaken for eggs by the uninitiated, but veritable eggs, which, if permitted to remain, produce larvae that will destroy the pupa. This is very easily prevented by crushing the eggs with a pair of fine-pointed pincers, being careful

not to include the epidermis of the larva. He must learn early to distinguish the larvae of *saw-flies* from the true caterpillar. These *false caterpillars* have globular heads and cylindrical, naked bodies, sometimes covered with a white flaky substance that easily rubs off, or have a dark-colored, slimy skin, and are either entirely deprived of abdominal legs, or have from *eighteen* to *twenty-two*, and are unarmed with hooks. The true caterpillar never has more than *ten abdominal legs*, which are always armed with minute hooks.

Every caterpillar undergoes periodical moultings, and they must on no account be disturbed whilst undergoing this change. When one of these periods arrive they cease to eat, and appear to be sick and languishing, remaining steadfastly fixed on some portion of their food plant, with the hooks of their false legs fastened in a little web of silk, and, even though irritated, are unwilling to change their position. It is always a critical time in the life of the larva, during which it not only changes its skin, but appears in one or two new dresses before reaching that characteristic of its maturity. The student should, therefore, learn early to recognize it, and to respect the necessities of the little creature of which he has made a captive. When larvae are dissatisfied with their food plant or about to change to pupae, they never indicate it in this manner, but traverse their place of confinement incessantly and restlessly, travelling over the same track until they wear it into a pathway.

The chief indications to be observed in rearing larvae is to place them in as nearly a natural condition as possible, and to keep their food plant fresh for the longest practicable period. In order to fulfil these conditions in all cases, something must be left to individual ingenuity and intelligence, but for the great majority of larvae I would heartily recommend the following elegant and easily constructed *vivarium:*

It consists of a circular wooden box, from six to twelve inches in diameter or more, at the option of the observer, and from four to six inches deep, lined with sheet zinc or lead, so as to be water-tight. A stratum about an inch or two inches thick of washed, fine gravel-stones is placed on the bottom, and the remaining space is filled with moistened but not wet loam, and the surface covered with moss. Into this various small, humble plants may be set for the purpose of generating oxygen, and consuming the carbonic acid gas exhaled by the larvae, and the whole is covered with a bell glass, that rests upon the rim, proportioned in height to the diameter of the box. When it is to be used, a portion of the food plant of the larva should be stuck into the moistened loam, where it will remain fresh quite a long time, in consequence of the atmosphere within the bell glass being saturated with watery vapor, which condenses on the sides, and trickles down to the soil again.

The arrangement of the earthy materials closely resembles that of natural soil, and if the transformation of the larva is subterranean, there is no necessity to remove it in order that it may undergo the change to a pupa. If the larva is a large one, or if it contains more than one, the bell glass should be elevated every few days, and their ejectamenta removed from the surface.

The glass merely stands on the rim of the box, and should not be perfectly air tight; and the vivarium should be exposed to the change of temperature between night and day, so that the included atmosphere, by its expansions and contractions, may be also renewed from the external air. It should never, however, be exposed to the direct rays of the sun, but always kept in the shade.

To those who may regard this apparatus too expensive, another form is recommended, but it is neither as convenient nor successful, except in the case of leaf miners and micro-lepidoptera. The top of a glass jar, at least five or six inches in diameter, is ground down on a piece of sheet lead with emery and water, so as to be perfectly level, and to receive accurately a piece of plate glass as a covering, in order to prevent the escape of moisture. The bottom of this is covered with moistened sand, a little loam, and the surface with moss. Into this the food, plant, and caterpillar may be introduced, with the expectation that the insect will do very well. It is, however, apt to become foul from the accumulated "frass," and is inconvenient to clean.

In order to rear leaf-mining larvae that never leave the leaf in which they are found, or at least not until about to transform, a common large drinking glass, the top of which has been ground level and covered with a piece of plate glass, answers a very good purpose. The bottom should be covered with *white sand*, moistened, but no water should be permitted to rest on the surface. It is not necessary, of course, to place in this apparatus anything more than the leaf, with a portion of its stem containing the leaf miner. The collector should provide himself with a tin canister in which to carry the leaves containing leaf miners during his entomological excursions.

A still cheaper and very effectual breeding cage consists of a frame of any convenient size, say twelve inches square, covered with bobbinet, and with a door in front. The bottom must be of wood, and the plant may be kept fresh for several days by inserting it in a vial half filled with water.

We have now to touch on what devolves upon the observer, in making use of these contrivances, to enable him to record the habits of larvae, and to make good and useful descriptions. In the history of the life of any being one of the most valuable traits of the observer is *truthfulness*, not that we mean to say any one would wilfully misrepresent what he sees, but that he should be truthful in recording what he sees and knows to be facts, not what he may imagine or conjecture; and however strange it may appear to those not familiar with these studies, the temptation or inducement to depart from what is evidently so proper is often strong and of frequent occurrence. Sometimes it is the consequence of hastiness or of inattention, or it is an apparently plain and obvious deduction; but the ways of nature sometimes surpass in strangeness the ways of our reasoning. All this involves the idea of accuracy in the description of natural objects, and it is far from easy to give a clear and graphic conception of larvae by attempting to represent its physical characteristics in words. The observer should not be content merely to describe the ornamentation of larvae, but should endeavor to give, in a clear and concise *word picture*, a definite conception of its *form, clothing, and external pecu-*

liarities; and if he can sketch and color natural objects with facility and accuracy, a collection of drawings representing the larvae, food-plant, and pupa would be very valuable and interesting.

There are certain terms employed by entomologists which will be of use to the observer, and which we will endeavor to explain.

Any particular family will always be found to show a variety of larval forms, which, whilst they conform to a certain type, indicate by their modifications the relationships existing in every direction between it and other families. Hence, whilst there is no standard or invariable larval form for any family, it may be well, by the employment of general terms, to give the novice some conception of the affinities, at least, of those which will most probably first attract his attention.

1. *Sphingiform* would, therefore, characterize larvae having naked bodies and a horn or shining lenticular tubercle on the eleventh ring, and broad, strong anal prolegs.

2. *Notodontiform larvae* generally have the body furnished with fleshy elevations, and usually hold the hind segments elevated.

3. *Chelonidiform larvae* have the body covered by long tnick hair, arranged in verticillate bunches or whorls, arising from verrucose points or warty excrescences.

4. *Geometriform larvae* are characterized by the absence of some of the abdominal prolegs, or the want of development in some of them.

5. *Catocaliform larvae* have the head rather small, flattened, and carry it horizontally; the body is semi-cylindrical, tapering anteriorly and posteriorly from the middle; a small transverse, fleshy ridge or prominence on the eleventh segment; the anal prolegs rather long and thrown backwards, generally the first two pairs of abdominal prolegs not well developed, and the rings of ventral surface marked with round spots; they arch the body in motion, particularly when young.

6. *Phaleniform larvae* consist of the geometers, properly so called, or *measuring worms;* they are characterized by the absence of the first three pairs of abdominal prolegs quite constantly, leaving but one pair of abdominal and one pair of anal prolegs, in all ten feet; the true or thoracic feet are placed on mammillons, which increase in size to the third pair; the body is generally cylindrical, and the middle segments longer than either those of the anterior or posterior portions; the eleventh segment is marked on the dorsum by a transverse ridge or small excrescences, and frequently the fourth, fifth, and eighth have fleshy excrescences or appendages.

7. *Uranidiform larvae* will be found possibly in southern Texas or in Florida; their forms are not well known. They are described as being either semi-geometrical—that is, having some of the prolegs absent or atrophied, arching their bodies when in motion, swollen in the middle, having two retractile tentacles on the head,(?) and living on the terebinthaceae; or they have sixteen feet complete, are thick, with deep incisions between the rings, a large head joined to the body without any intermediate constriction, the first segment having a corneous and shining shield, and the body furnished with quite long isolated hairs; they hide during day under a transparent web of silk

spun amongst the leaves. Both forms are of large size, and are tropical insects.

8. *Liparidiform larvae* are simply hairy, and generally with brushes and long tufts of hair in addition.

9. *Saturnidiform larvae* have thick, heavy bodies, deeply incised, and furnished usually with rows of blunt or slender acute rigid spines, and large, strong anal prolegs.

10. *Ceratocampiform larvae* are also furnished with rows of roughened acute tubercles, but have long rigid horns on the anterior rings.

11. *Cochliopodiform* or *onisciform larvae* are very short and small, either semi-cylindrical or oval, having no visible head, being retractile, nor visible feet or prolegs. The whole surface of the abdomen is applied to the object to which they adhere. We have many most remarkable forms of this family.

12. *Gastropachiform larvae* are nearly naked, semi-cylindrical, very much flattened beneath, *with fleshy protuberances* or *tufts of hair above the legs*. They are generally found flatly applied to trees, the bark of which they resemble.

13. *Psychidiform larvae*, or basket-carriers, inhabit silken cases, and attach pieces of leaves, sticks, &c., to the outside.

14. *Tortriciform larvae* and *tineiform larvae*, except among the leaf miners, differ but little in form. They are generally of small size, smooth, semi-cylindrical, tapering anteriorly and posteriorly, with a semi-elliptical horizontal head. The former usually roll and bind leaves together, and the latter live in cases made of portions of leaves, &c., or in seeds, fungi, on rotten wood and decaying vegetable substances, or in the interior of leaves between their cuticles.

There are a few very convenient terms which should be used in describing the ornamentation of larvae.

The *dorsal line* is a colored longitudinal line on the middle of the back of the larvae, and follows the course of the dorsal vessel.

The *sub-dorsal line* is also longitudinal, and placed nearly or quite at an equal distance from the dorsal and the following:

The *stigmatal*, which is placed on the sides a little above the feet, and about the height of the stigmatal or breathing holes.

The *papiliform points* are dots on the body of larvae, nearly plain, and scarcely elevated above the surface, each giving rise to a hair. When they are rougher and more salient, and give rise to one or more visible hairs, they are called—

The *verrucose points*, and, as well as the above, are usually disposed on the dorsum in a more or less restricted trapezoid, or in squares.

The *dorsal region* is that portion included between the sub-dorsal lines.

The *lateral region* is that between the sub-dorsal and stigmatal lines.

The *ventral region*, all the portion below the stigmatal lines.

The *cervical shield* is a corneous plate on the dorsum of the first ring.

Shagreened or *granulated*, when the skin of larvae is roughened by minute raised grains, but at the same time naked.

Naked or *smooth*, when the cuticle is without appendages or covering of hairs.

Scabrous, when any portion is roughly and acutely shagreened.

Tubercles are hardened elevations, *spined, scabrous, plain, cylindrical,* or *lenticular.*

Spines are rigid, slender, and acute, and resemble small thorns.

Compound spines, a stalk furnished with numerous simple spines.

Hairs are fine dermal appendages like the ordinary hair; they are arranged in *tufts, pencils,* or are *verticillate.*

Horns are projections from the surface either corneous or fleshy, and are *simple, spined, rigid, roughened, flexible, fleshy,* or *penniform.*

Velvety, when the surface is clothed with soft short hair.

Hairy, when covered with hair either in tufts or verticillate bunches.

Mammillated, when short fleshy projections exist; they are *simple, spined,* or *hairy;* also called *papillae.*

Attenuated, when the body diminishes in breadth anteriorly or posteriorly.

Moniliform, when the rings are separated by deep incisions and resemble a succession of globular bodies like beads.

Cylindrical and *sub-cylindrical*, when the body has these geometrical forms.

Elongated, when the body is slender and appears to have been drawn out.

Bristles resemble hairs, but are stiff and rather rigid.

The direction in which the longitudinal diameter of the head stands to the axis of the body is—

Horizontal, when they form one plane.

Nutant, when its long diameter forms an obtuse angle with the body.

Perpendicular, when a right angle is formed with the axis of the body.

Respecting its connexion with the body, it is—

Free, when distinctly visible and not covered by the first ring.

Inserted or *retracted*, when the occiput, or top, is partly concealed.

Concealed, when entirely withdrawn within the first ring, or is covered by it.

Retractile, when a concealed head can be thrust out.

Elevated, when the top of the vertex is above the level of the dorsum or back.

Bifid, when the vertex is divided into two distinct lobes.

The object in following larvae through their embryonic development is to obtain a full and complete history of the species. A good description, therefore, should correspond to the particulars detailed below, arranged, in the first place, at the option of the observer, but, when completed for each species, should begin with a description of the egg, and follow the history to the development of the perfect insect.

1°. *The date when the larvae was found, and under what conditions.*

2°. *The name of its food plant, botanical and common.*

3°. *A description of its physical peculiarities;* commencing with the head, its size as compared to the body, form, position, and relations to the body; then the general form of the body, whether it varies from the cylindrical, and how, whether attenuated anteriorly or posteriorly, or swollen or prominent in any portion or deeply incised, and

the relation of the segments to each other; all protuberances should be designated, and the nature of the dermal appendages, if any, noticed; the number of feet, abdominal and anal prolegs, and the position of the latter with reference to the plane of the body, on what rings they are absent or are weakly developed, or are modified. To indicate the number and situation of the legs and prolegs, I use the following formula, which is not intended to supplant description: Every larvae having *thirteen* segments, including the head, the dots indicate segments without feet thus: $(\cdot\frac{3}{3}\cdot\cdot\frac{4}{4}\cdot\cdot\frac{1}{1})$. The formula represents the most common form, that having sixteen legs.

4°. *Its peculiarities of coloring;* giving first the general color of both head and body, and then the ornamentation on each.

5°. *The date at which it began to prepare for pupation, and the nature of its preparations.*

6°. *A description of the pupa itself.* It is not advisable, usually, to make a description of this from the first or a single specimen.

7°. *The date at which it became a perfect insect, and method of its escape from the cocoon, if it has one.*

8°. *The number of broods of the perfect insect* during one season, and whether the period of larval development is annual or bi-annual.

The observer should also endeavor to ascertain and describe—

9°. *The egg of the perfect insect,* its form, color, and peculiar markings under a lens. When the perfect insect of a larvae is once known, this and the following can be ascertained by preserving the egg layer.

10°. *The appearance of the young larva* on first emerging from the egg; the successive changes in appearance it undergoes during its moultings until it reaches the condition indicative of maturity.

11°. *The habits of the larva,* including everything pertaining to larval life, from the time of leaving the egg to maturity, whether characteristic or not.

12°. *The habits of the perfect insect,* as far as they can be ascertained.

The student should begin, in the first instance, with the endeavor to refer his caterpillar to one of the larval forms characterized heretofore, in order to gather his descriptions under general heads. Probably he will not be successful in referring it to any there indicated, for several groups have been omitted in consequence of the difficulty of representing them by any graphic characters. These he may arrange under any general heading that appears most appropriate to himself. Each vessel containing a larva should be marked with a special numeral, beginning with *one* for the first, and so on, and the description should be indicated by the *same number;* if the pupa is removed from the vivarium in order to receive another larva, (for two dissimilar larvae should never be placed in the same vessel at one time,) that containing the pupa should be designated by the number referring to the description of the larva, and the numeral should be marked on a little square of paper and fixed on the pin containing the perfect insect when it appears and has been killed and pinned. A specimen of the mature larva described, whenever it can be obtained, should be drowned in alcohol and enclosed in a piece of foil, such as is now commonly used for wrapping fine-cut tobacco, with

the number referring to its description, *in pencil*, on a slip of paper. Thus prepared, it should be dropped into a bottle of alcohol, together with the cocoon and pupa, or pupa alone, if it has no cocoon, treated in a similar manner, and marked with same number. When the student desires to forward his collection to the Smithsonian Institution, the bottles containing the larvae and pupae should have the tops filled with cotton, then completely filled with liquid to prevent the agitation of its contents, and tightly corked. *The name* and *locality of the collector* should be written on the top, as also on the box containing perfect insects, and on the copy of his notes. When it is possible to obtain them, at least from *three* to *six* specimens of the *same species* of perfect insects are desirable.

I would recommend those who are desirous of becoming better acquainted with the subject of entomology, and of acquiring some insight into the classification of Lepidoptera, to obtain The Introduction to Entomology, by Kirby and Spence, republished by Lea & Blanchard, Philadelphia, in addition to "A Treatise on some of the Insects of New England which are Injurious to Vegetation. By Thaddeus William Harris, M. D. Boston: Printed by White & Potter." There is also another work published by the State of New York in its natural history series, the chief merit of which, at least with respect to Lepidoptera, consists in its rather indifferent plates. It is much more expensive than Dr. Harris' treatise, and by no means as reliable, but may enable the student to ascertain the names of some species by comparing the perfect insects with the plates. Besides these works there is also a Catalogue of the North American Sphinges, by Dr. Harris, in the 36th volume of Silliman's Journal of Science and Art, 1839; and the Academy of Natural Sciences in Philadelphia will soon publish a synopsis of the same family, representing the present state of its classification, and describing all the new species which have been discovered up to the present time. This can be obtained by students and observers, upon application, for the cost of paper and press-work, which will be comparatively nominal. This paper will be followed by synopses of other families as rapidly as they can be worked up, one of the most serious difficulties being that of obtaining specimens of all the perfect insects described by foreign naturalists. If, therefore, those who intend to collect for the Institution would commence during the present season, and forward to Washington a box of perfect insects from their respective localities, it will facilitate the labors of those engaged at present in the study and hasten the development of this portion of entomological science in the United States. Any observations the student may desire to make public should be transmitted to the Academy of Natural Sciences in Philadelphia for publication in their "Proceedings."

THE PUPAE.

The larvae that issue from the egg of the perfect insect in early spring reach their full development about its latter portion, and entering the pupa state, appear as perfect insects usually in about *two or three weeks*. The representatives of these, generally speaking, do not become pupae until the beginning of the fall and remain in this con-

dition throughout the winter, emerging as *imago* during the succeeding spring. The observer should therefore begin his search for young larvae and eggs with the first appearance of vegetation, and either make them captives or mark the places where they may be found; but in general the former is preferable. Feeding and rearing larvae in spring time has also this advantage: that the food-plant is kept fresh longer and with less difficulty than in the latter part of summer and the autumn, and specimens of the perfect insects are obtained the same season.

After the insect has changed to the pupa it should not be unnecessarily disturbed, and never handled with the fingers, except when it cannot be avoided, and then the utmost gentleness of pressure should be used. This applies more particularly to pupa which have been developed in the atmosphere of the vivarium, where its humidity prevents the hardening of the pupa case as completely and rapidly as it takes place in the external air. When it is removed from the vivarium it should be placed as nearly as possible in the same condition that the larva chose for it, and the new vessel containing it should be designated by the number of its caterpillar, so that the perfect insect may be referred properly to its larva. The observer need not be solicitous about the apparent impossibility of the perfect insect making its escape from very dense cocoons, and attempt to aid them by opening them; nature has provided a very efficient and powerful means to effect what is at first view, and what naturalists themselves have regarded, a most curious puzzle. Without entering into particulars, I may say here that the effective and only agent by which this is accomplished is the action of the powerful *thoracic muscles.* The larvae of the fall months should not be disturbed after entering the ground, for many of them *hybernate* until spring in their cells or cocoons made on the surface when they change to pupae.

The pupae of *cochliopodiform* or *onisciform larvae* are always enclosed in a small ovoid, brittle, silky cocoon, and are difficult to bring to maturity. The larvae hybernate in them until the following spring, when they change into pupae covered by a very thin and delicate pupae case. Their cocoons should be permitted to remain amongst the moss where they are usually woven, and the moss should be kept moist and exposed to the external air beneath some convenient and protecting shelter, and covered with a layer of fine, dried grass during winter. I have found a great number of very remarkable forms belonging to this family, but as it was during the period of my own inexperience in rearing larvæ, and being unable to obtain hints from others or from books, for there are none I believe in which the subject is treated, I lost the greater portion of them and have since looked vainly for other specimens.

The vessel containing pupae should always be provided with objects, such as portions of the branch of a tree, fixed in the ground, in order that the imago when it appears may ascend one of them and expand its wings. For when they first appear their wings are undeveloped, flaccid and moist; they immediately ascend the first encountered object that is perpendicular or nearly so, and seek to place themselves in such a position that their wings may be *dependent or hang downwards from the back.* Then they begin to grow and develop

themselves in every direction, and spots which were previously very small in consequence of the overlapping of the scales, when the process is completed, have twice or thrice the original dimensions. The process of wing expansion should not be permitted to take place in the moist atmosphere of the vivarium, except in the "micros," nor should the insect be disturbed or killed until after it begins to use its wings voluntarily; otherwise it will be difficult to make good preparations of the wings. These bred insects on first being handled or when they first feel the effect of chloroform, void a quantity of excrementitious matter, which the student must be careful does not soil the wings.

The practice of the old trans-Atlantic collectors of obtaining pupae by digging for them at the roots of trees has been recently revived in England with the most successful results by the Rev. Joseph Greene. He says that "meadows and parks, with scattered timber trees, are generally the best localities; next to meadows and parks come woods; but searching in woods is a tedious and fatiguing affair, and requires some experience; it is in vain to examine the dense portions, it is equally vain to dig at the roots of trees in such localities, and you will rarely find anything unless upon trees of considerable growth; the thick moss which collects about the trunks and roots is the part to be examined. *Bombyces* are generally found under the moss which covers spreading *roots* and not on the trunks, which seem to be preferred by the *Geometrae*. The best localities in woods are the *borders* or *open places;* such places when elevated or facing the north are generally the most productive. The only instrument I use is a common garden trowel; the form is immaterial, perhaps a rounded blade is best, as passing with greater ease between the roots. The trees which I have found the most productive are the following: elm, oak, ash, poplar, beech, willow, and alder. [I would likewise add, for the American collector, the walnut, the wild cherry, the apple tree, the linden, and the hickory.] In digging, it must be borne in mind that all pupae are close to the trunk of the tree, seldom more than two inches distant; frequently the trunk of the tree forms one side of the cocoon, especially the cocoon of such insects as spin; the chrysalis also lies almost invariably close to the surface of the earth. Insert the trowel about three inches from the trunk, to the depth of two inches or so; then push it to the tree and turn up; if the soil be dry and friable, without grass, knock it gently with the trowel, which will be sufficient. If, however, there be grass, you must proceed more cautiously; take up the sod on the left hand, knock it very gently with the trowel, and those pupæ which merely enter the ground will drop out; to find those which spin, you must carefully examine the sod, tearing the roots of the grass asunder; these are, of course, much the most difficult to find, the cocoons being generally of the color of the earth. It is useless to try sticky or clayey grounds, the caterpillars being unable to penetrate it; in searching under moss the best plan is to loosen the edge, then to tear it gently off, observing whether any pupae fall. Look at the trunk of the tree to see if anything adheres to it, and then carefully examine the moss itself; experience alone will enable you to detect a spun cocoon.

In another place Mr. Green remarks: "With regard to localities, the best are unquestionably parks and meadows with scattered timber trees. Those trees from which the surrounding grass has been worn away by the feet of cattle, and those situated on the borders or banks of streams, dykes, &c., when the soil is dry and friable, will be found the most remunerative. When the roots of trees, particularly large ones standing alone, form angles, pupæ will nearly always be found in the spaces; the trowel should then be inserted at least eight inches from the trunk and to the depth of about four. In digging *round* a tree, whose roots form no angles, it is not necessary to go deeper than three inches, nor farther from the trunk than four. Always *replace* the sod when you have done with it, or at least the débris. When first taken up, the sod may be so hard as to render it impossible for the caterpillar to penetrate it; but if, after being loosened by the pupæ-digger's manipulation, it be restored to its place, the larva, which, in the original instance, would have wandered away to some more convenient spot, will now find one ready made, and will almost certainly make use of it."

"He should have a small box, filled with damp moss, for the purpose of carrying the pupæ, which should be handled as seldom as possible, and with the utmost tenderness. I may here remark, that some of the pupæ may dry up. This is caused by some unlucky, probably *unseen*, injury, inflicted at the time of capture, and, however great his caution, will not unfrequently occur." The best months for digging are July and August for the summer and autumn specimens, and September, October, and November, for the following spring and summer insects. Mr. Green has found the months of September and October the most remunerative to the pupæ hunter.

In order to rear the pupæ thus collected, "when brought home they should be placed in a large box, with the inside surface *rough*, and covered with gauze or wire frame; at the bottom of the box should be some fine earth on which the pupæ are to be placed and covered with a thick layer of moss, which may or may not be occasionally damped. *Be sure to keep them from the sun.*" It is best also to keep them exposed to the external air during winter. The one obvious principle to be observed, as far as possible, is always to place them under the natural conditions in which they were first found. The student may also derive from pupæ hunting valuable hints, at least respecting the food plants of many larvæ, and the periods of the season during which they may be found near maturity.

HOW TO PACK LEPIDOPTERA FOR EXCHANGE, ETC.

In order to send insects to a distance safely, a box well made, of light, thin material, should be obtained. It should be double, the two portions attached together by hinges, and the bottoms lined with cork, glued down, and covered with unsized paper; it should be about twelve inches square, and each portion an inch and one-half deep, before the cork lining is added; but if the collector uses pins longer than an inch and a fourth it should be deeper. The pins containing specimens should be introduced firmly in the cork, and enough of the

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pin should always be exposed to permit it to take a good hold; and if the abdomen be large and heavy it should be supported by cross pins: that is, two or more fixed crosswise over this portion of the body, with a pellet of cotton fixed on the pin beneath and drawn under the abdomen, so that it will rest on it. If the specimens are placed very high on the pins, and raised considerably above the surface, the pin should be first passed through a little cotton, and the specimen permitted to rest on it, or the whole surface may be covered first with a layer of cotton. A large number of specimens may be secured in the box by pinning one over half the other, like shingles on a roof.

When the box is filled with specimens, the front should be secured by a little hook and socket; and it should be then wrapped in several thicknesses of cotton wool, and the whole enclosed in a piece of cotton sheeting made secure with a needle and thread. The object of wrapping the box well in cotton is to prevent the specimens being broken or injured by any jar or concussion the box may receive during transmission from one place to another. Bottles containing specimens of larvæ, &c., in alcohol, should be enveloped in cotton and enclosed in a paper box.

It may happen, sometimes, that those who desire to collect may be in such a position that none of the expedients heretofore mentioned may be available. Expeditions to the new countries of the west, or persons stationed at military outposts and forts in the Indian territories, may be unable to obtain pins, or the agents heretofore mentioned as being used for destroying the life of Lepidoptera, and will be, of course, unable to make preparations in the ordinary manner. As specimens from the Territories would be exceedingly interesting, in order to anticipate the condition of those at military outposts and stations who would be willing to advance the cause of natural history by collecting, I will suggest how it can be accomplished without any of the conveniences heretofore mentioned.

If the spirits of ammonia cannot be obtained, insects may be killed by the fumes of one or two sulphur matches, after having been confined under a glass, or by means of tobacco smoke, or by pinching the thorax, as heretofore described. The wings should be then turned upward, so as to be perpendicular to the back or erect, together with the antennae or feelers situated on the head, and placed in this position between a few folds of porous paper, and submitted to light pressure until they have become partially dried, and the wings will retain their position. They should then be placed on a square piece of paper, which should be folded in a triangular form, and the open ends of the sides turned over, so as to admit of as little motion to the included specimen as possible. These papers, properly marked as to localities, may afterwards be packed between layers of cotton in paper boxes, or in any manner most convenient to the collector, provided they are not submitted to pressure.

We can imagine no more pleasant and healthful employment during leisure and unoccupied hours for the men who are stationed at the military outposts of the Indian territories than collecting these objects of natural history; and we would respectfully call the attention of their officers, many of whom have shown so much intelligence and

manifested so much interest in the collection of specimens belonging to other classes, to the advantages which may result from it both to those under their care and to entomology itself. If we remember aright, the British government authorized such collections to be made some years since in the neighborhood of the military stations in Canada, with the most gratifying results, both to those engaged in collecting and to this branch of natural history.

CABINETS, IMPLEMENTS, ETC.

The ring net is made of bobbinet of fine mesh, or, what is much better, book muslin, and should be cut in three pieces, the sides of which are rounded from the base to the apex, so that when sewed together the net will have the form of a sugar loaf. It should be rounded at the apex, and the circumference of the base, previous to being fixed on the ring, should be somewhat more than the ring itself. This may be moderately thick iron or brass wire, and should be from eight to twelve inches in diameter. The depth of the net should be at least once and a half that of the diameter of the ring, so that the bottom may be thrown over the top of the ring by a twist of the rod. This is frequently necessary, when a large and active moth has been taken. An iron socket, with a male screw on the end, may be made to receive the bent ends of the ring; or these may be fixed in a piece of tubing by means of melted lead, one end being left open to receive the rod; or the bent ends of the wire may be fixed directly to the end of the rod itself. The rod should not be more than three or four feet long.

Any substitutes for cork will answer only for cabinet use; there is nothing that will supply its place in the exchange box. The following substitutes have been recommended on account of their cheapness: "Inodorous felt" is cut to fit the bottom of the boxes and glued to the surface, and then covered with paper, or thick ironing blanket is used for the same purpose. "Cut the blanket the size of the drawer or box and glue it down with good fresh glue; when perfectly dry, soak it well with fresh paste, and paste one side of the paper also, place the paper on the blanket, and smooth it well down with a warm linen cloth. In four days it will, in a favorable situation, be fit to hold insects." The sheet cork may be cut into strips, if one wishes to economize, and glued in drawers or boxes, at a sufficient distance from each other to admit of the specimens being arranged in rows.

The preservation of specimens after a collection has been once made is by no means simple or easy; they should not be exposed to the light of day, because many species in the course of time are deprived by the light of their brilliancy of color, and become faded; and hence being kept in darkness, and the objects generally of merely occasional inspection, they are apt to be destroyed by various insects that live on dried animal substances, such as mites, the larvae of a species of coleopterous insect, an *Anthrœnus*, and the larva of a species of *Tinea*, which makes its case of the scales and portions of the moths. When the two latter have been permitted through neglect to accumulate in a collection, the only certain mode of putting an end to their ravages, and

at the same time to destroy the unhatched eggs, is to submit them to a degree of heat sufficient to coagulate albumen. This is accomplished by placing the box in an oven, turning the open portion downward, and elevating it a little above the surface by means of supports so that they may not be burned, and the insects themselves must be watched lest they are scorched by the heat. The heat will soon dislodge the larvae, which falling on the heated surface are killed, and the albumen of the eggs is coagulated; thus preventing the development of those in ova. I am acquainted with no means of preventing the invasions of the anthreni, except perfect seclusion of the objects themselves; it is usual to recommend the introduction of lumps of camphor into drawers and boxes, but it has very little effect on them; the English entomologists use a few drops of *Borneate of Petroline*, (probably a mixture of oil of camphor and petroleum,) but as I have never seen it nor used it, I can say nothing respecting its efficiency. According to my experience, too, it is useless to paint the bodies with a strong solution of corrosive sublimate; it spoils the specimens and does not protect them. I have also tried disembowelling the large moths and stuffing them with cotton, subsequently saturating it with corrosive sublimate; but this does not protect the thorax against their ravages. The boxes and drawers of a collection should therefore be inspected frequently, for the purpose of ascertaining if any destructive insects are present, this being immediately revealed to the eye by a little heap of dust or excrement beneath the specimens attacked.

The collection may be kept either in drawers covered with glass, or in wooden boxes; the latter should be three inches deep and twelve by eighteen or twenty inches clear measurements, opening in the centre of the depth on hinges, and defended from dust by a short *rabbet* around the inside of the lower portion. The boxes should have one of their measurements about twelve inches, because the cork is usually cut in pieces about this length. A cabinet of drawers, each lined with cork and covered with a glass, enables one to view the insects without danger of accident by touch, but it would be more expensive than simple boxes. Mr. Titian Peale, of Washington City, has an extensive cabinet, which for beauty, security, and convenience, excels anything I have ever seen. The cases consist of a light square frame about twelve inches by nine inches, which are bound in an ordinary cover like a folio volume, and arranged on the shelves of a case like books; the frame is supplied with a glass on each side and made perfectly tight in grooves by means of thin foil. The space the insect occupies having been previously ascertained, a section of a cork for vials is fixed to the glass, together with the number of the specimen, by means of black varnish. This arrangement enables one to examine both sides of the expanded insect without any difficulty, and excludes insects and dust completely. It will be a source of pleasure to Mr. Peale, I am sure, to give those who are desirous of forming a cabinet in imitation of his plan more specific directions than I can respecting the construction of these entomological volumes. He assured me they are not expensive, and that any one can soon learn to make and bind them as they are wanted, as he himself has been in the practice of doing for many years. His collection has been in his possession more

than twenty years, and he has never lost a specimen during that period from the ravages of other insects; those, therefore, who wish to accumulate a cabinet would do well to commence from the beginning on a plan which will release them from all future care respecting it, besides forming a most appropriate ornament either for study or parlor.

We have now reached the conclusion of a pleasing task, undertaken in the hope that it might subserve the purpose of leading many active, intelligent, and inquiring minds to observe the little people of the insect world, to share the delights, pleasures, and knowledge that communication with Nature never fails to bestow, or to contend for the honorable distinctions which always follow an earnest and persevering devotion to the study of natural history. As this paper is intended chiefly for the use of the novice, we have sought simply to show how that which is manipulative can be best performed, and to record such experience as might benefit them on their entrance into this new world. It is, I know, looked upon as insignificant, the domain of plagues, pests, and human annoyances, by many, a great many in our own country who should be better informed, but are, perhaps, unobserving and unreflecting, and the attention and study given to these beings considered a waste of the fleeting hours of life which should be devoted to lofty and noble purposes. They forget, or do not know, that the works of Nature are all alike intricately planned, the result of thought and premeditation which binds the most dissimilar departments into intimate and dependent relationships, that no one can be studied without involving a knowledge of the others, which meet us boldly and constantly face to face on every pathway of knowledge. They forget that all branches of natural science are but little rays of light emanating from the great source of it all, lighting up and beautifying the human soul, which is endowed with capacities to absorb it and assimilate it to itself; and thus the occupation of the students of God's works, unlike that of the patient alchemists of olden time, who sought to seize the occult mysteries, transmutation and immortality, becomes an effort to accumulate and illustrate those truths, which transmute disbelief into golden thought and life-invigorating faith. Do not the lives of many votaries of natural science verify the pretension? The tearful life of the great Swammerdam, the patient and accurate historian, the acute and tender investigator of the lives and structure of the insect, who, had he enriched the world with that emanation of his genius the *microscope alone*, and left unwritten his great and immortal work, would have been entitled to the gratitude of every lover of knowledge—to an immortality of praise. Poor, and almost friendless, he became, perhaps, the originator of the science of entomology; and I can see him, even now, choosing rather to follow heaven's own light than to abandon it for the ease of an exacting parent's hearthstone, wandering houseless and needy through the ancient streets of Amsterdam, spurned from the doors that should have been opened to receive him, and disinherited of a patrimony that to him would have been princely, contemplating painfully the necessity of separating himself for gold from the cherished objects of careful accumulation and study, his frame

shattered and emaciated by an insidious fever, excessive application and the wolf-like gnawings of gaunt want, but patient and gentle, self devoted and undiscouraged, and in the midst of all the gloom and disappointments of a laborious and short career, in the very last hours of life finding a tender consolation in the friendship and religious mysticism of Antonia Bourignon, until death gently and slowly led the great, good soul down to his secluded valley, and bade him rest and sleep. But still he does not sleep; his memory lives to animate many desponding minds, to invigorate many faint hearts.

The pages of entomological history are adorned, too, by the names of many of the gentler sex, and their accomplishments and graces have served to beautify the study. The sympathy of woman with all that is tender and beautiful in nature, the delicacy and facility with which they manipulate minute objects, would seem to indicate this study as one which should be with them a favorite and congenial pursuit; and I could instance at least one example of its successful cultivation in our own country, if I deemed it proper, without appealing to the magnificent works of the heroic Maria Sibilla de Merian, or the minute and pains-taking investigations of Mademoiselle Jurine. "I have seen the young London beauty," says the eloquent Kingsley, in Glaucus, "amid all the excitement and temptation of luxury and flattery, with her heart pure and her mind occupied in a boudoir full of shells and fossils, flowers and sea-weeds, and keeping herself unspotted from the world by considering the lilies of the field, how they grow." The feelings of repulsiveness with which insects are so frequently regarded, arising from antipathies produced by false education and false ideas, soon vanish when once we become acquainted with their lives. We recognize in each species a distinct and individual biography. We perceive they are influenced by many of the same passions and instincts that animate the higher animals; that their existence presents a marked and striking contrast even to our own. Ours is ushered by the beautiful, bright days of fresh youth, during which we seem to flutter idly from pleasure to pleasure, only to descend surely and slowly to the dark and languid days of decrepit age; while theirs is entered upon in sombreness and toil, and weighed down in unwieldy and unattractive forms, to rise at last from its long obscurity to the sweet sunlight and the blue heavens, to a youthfulness in which they die glorified. Everything, indeed, in the little lives we would endeavor to interpret and understand, appeals harmoniously to our sympathies, even the coincidences of nature established for their well being, or which glide into their histories. Let us mark a coincidence. The soft voice of springtime, and its warmest breath, arouses vegetation from its long night of winter sleep, and we admire the early flowers rising from the earth, and opening glad eyes in the sunlight, till on the green hill-sides and the meadows is spread an inviting banquet. And even whilst we ask ourselves for whom, or what, all this decoration and renovation of prairie and hill-side is intended—for whom the magnificent festive board is spread? the answer is brought to our ears, when at the same time the influence which has awakened vegetation calls forth from the waters, the earth, and places of cunning concealment, the insects, whose structure and forms declare they were

designed to be the presiding revellers in a scene so full of poetry and beauty.

The most active and ardent, as well as delicately constituted natures and minds, will always find enough to interest and stimulate them in this study; leading them gradually onward in the simple path of observation to obscure questions and more intricate problems, which become clear and light under the touch of rightly directed investigation. It is quite impossible, however, that every one should be a naturalist; but there are few who may not with care and the cultivation of habits of accuracy become most excellent observers, improve thereby their general health, and extend the range of their daily pleasures and the congenial and invigorating friendships, which result from the mutual predilections for the same branch of knowledge. The beginner to whom the subject is novel will doubtless meet with many sources of discouragement, but it should only serve to stimulate him to increased application, and inculcate lessons of patience and heedfulness. He will be compelled to acquire the simple technical knowledge in ordinary use, and which can be met with in almost any entomological work; and this done, he can then confine himself to detailing the histories of larvæ development, or subsequently engage in the more complicated study of classification, which the information he has obtained by observation will the more readily enable him to understand, in the special expositions of the relations of these beings to each other. The object of these remarks is to *encourage observation* and the practice of recording its results, especially amongst those who are conscious they can do so clearly and well, quite as much as the accumulation of collections of perfect insects. The necessity which demands the former may be conceived from the fact that the history of scarcely any of our described Lepidoptera is known in all its essential particulars, and therefore attention can scarcely be given to this subject and be unrewarded by some good results. The *note book* should be the inseparable companion of the observer, and every fact detailed, every observation recorded; no matter how trivial it may appear at the time, no one will be inclined to laugh at it, except those whose wit lies on the surface of life "as idle as a painted ship upon a painted ocean." And then, how worse than useless it is to devote time to an object at once praiseworthy and beneficial, yet leave no marks of your progress and labor, by which others may be spared the necessity of traversing the same round of observation which you had long since performed but neglected to render available to whomsoever might be attracted to the same course of study. There never comes to my knowledge an instance of this kind without vividly recalling the unworthy servant and his single talent, and I am tempted to exclaim, he is justly deprived of the honors and distinctions he might have shared, inasmuch as he has selfishly buried his "talent" in the recesses of his own mind.

"Some, perhaps, of those who read the preceding remarks will ask, What is the *use* of entomology? These I would ask to consider what they mean by *use;* they will find, I think, though they may not like to confess it, that their idea of a useful thing is, a thing which can be turned into money. But money itself is only valuable in as

far as it contributes to happiness, whether bodily or mental; and even if the tendency to health, which is given by the regular habits, temperance and industry, without which no one can be an entomologist, are to be considered of no value, still the constant interest without anxiety or disappointment, the gentle exertion without overstraining the mind, and the contemplation of the universal beneficence of the Creator even towards the smallest of his creatures, can hardly fail to bring to the mind a peaceful happiness which none but a philosopher can appreciate, and even he cannot describe. If, indeed, he could, instead of the few who devote themselves to the study and observation of animated nature, there would be scarcely any who would not become naturalists."

Let it not, however, be supposed that the way to philosophic heights is smooth and easy, and that the book of Nature can be read without first acquiring the alphabet in which it is written. But whilst its pages invite all to investigation, even those who run the course of a busy life, its records can be fully deciphered only, perhaps, by those few chosen spirits whom she has selected as her interpreters, who pass through a long and laborious pupilage, who are content to labor without other hope of reward than that which knowledge brings, and to sit childlike at her feet, learning to lisp the accents of the language in which she expresses her startling and profound conceptions. And without aspiring to deep acquirements, without seeking to merit the designation of naturalists, we can prepare the way for the advent of this chosen spirit in the field of entomology in America, and feel ourselves elevated in mind and benefitted in body by the devotion of leisure time to intelligent and systematic observation of even those beings which may have been heretofore considered unworthy of notice, but which at least teach us that "there's never a leaf or a blade too mean to be some happy creatures palace." It will be a most acceptable labor to the intelligent everywhere, and in the end must convince the most practical minded that "Whatever it has been worth God's while to create, it must be worth man's while to study."

AN ACCOUNT OF THE GRASSHOPPERS AND LOCUSTS OF AMERICA, CONDENSED FROM AN ARTICLE WRITTEN AND FURNISHED BY ALEXANDER S. TAYLOR, ESQ., OF MONTEREY, CALIFORNIA.

From the periodical press we learn that, up to the 11th of October, 1855, and commencing about the middle of May, these insects extended themselves over a space of the earth's surface much greater than has ever before been noted. They covered the entire Territories of Washington and Oregon, and every valley of the State of California, ranging from the Pacific ocean to the eastern base of the Sierra Nevada; the entire Territories of Utah and New Mexico; the immense grassy prairies lying on the eastern slopes of the Rocky Mountains; the dry mountain valleys of the republic of Mexico, and the countries

of Lower California and Central America, and also those portions of the State of Texas which resemble, in physical characteristics, Utah and California. The records prove that the locusts extended themselves, in one year, over a surface comprised within thirty-eight degrees of latitude, and, in the broadest part, eighteen degrees of longitude.

On several days in June, July, and August, of 1855, the grasshoppers (or *langostas* of the Spaniards) were seen in such incredible numbers in the valley of Sacramento, in California; in the valley of Colima, in Southwest Mexico; in the valley of the Great Salt Lake; in Western Texas, and certain valleys of Central America, that they filled the air, like flakes of snow on a winter's day, and attacked everything green or succulent with a voracity and despatch destructive to the hopes of agriculturists.

To stimulate inquiries founded on original observation of the locust, Col. Warren, editor of the California Farmer, forwarded a short circular note to several periodicals, dated July 2, 1855, in which he states that, "for the last three days, the very air has been so full of them over this city (Sacramento) as to resemble a dense snow storm. Large fields of oats and wheat have suffered in Ione and other upper (Sierra Nevada) valleys."

The Sacramento Union, of the same date, states that the "most remarkable circumstance we have ever been called on to notice in this locality was the flight of the grasshoppers on Saturday and yesterday. For about three hours in the middle of the day the air, at an elevation of about two hundred feet, was literally thick with them, flying in the direction of Yolo. They could be the more readily perceived by looking in the direction of the sun. Great numbers fell upon the streets on Saturday—absolutely taking the city by storm—and yesterday they commenced the wholesale destruction of everything green in the gardens of the neighborhood. Their flight, *en masse*, resembled a thick snow-storm, and their depredations the sweep of a scythe. The prevalence of the scourge is explained by Dr. T. M. Logan as being attributable to the great warmth and dryness of the present season—circumstances favorable to an early development of the eggs of the insect, which is deemed one of the most fruitful in the animal kingdom."

The Shasta Courier, printed in the northern Sacramento mountains, remarks that "on Wednesday last (September 19, 1855,) an immense flight of grasshoppers passed over this place, flying westward. The greater portion of them flew very high, and could only be seen by shading the eyes from the sun. They were as thick in the heavens as flakes of snow in a winter storm."

The Sacramento Valley papers mention that whole orchards, gardens, and vineyards have been consumed by them. Entire fields of young grain, of crops, and vegetables, have been eaten up within the space of a single day, leaving the ground like a wilted, blackened desert. In some parts of the valley they annoyed the passengers and horses of the public stages to such an extent as to cause the greatest inconvenience, and appear, in some cases, to have positively endangered human life.

A gentleman who resided in Colusi county, in the Sacramento

valley, in the summer of 1855, informs us that these insects appeared to rise out of the eastern boundaries of the valley, where it is hot, dry, and sandy, and that, on some days, they filled the air so as to obscure the sun. They consumed all garden vegetables, the leaves and bark of the elder tree, and the young leaves and bark of the small branches of the cotton-wood and willow, and even the soft, green parts of the tules or bullrushes. In Stony Creek, in the same county, their dead bodies were seen, at one time, completely covering the surface of the water for miles in extent. In some parts of this valley they ate through gauze and textile coverings of all kinds, which had been used to shield animals and plants from their attacks.

The grasshoppers appeared in 1855 in much larger numbers in the valley of the Sacramento and the mountains which bound it on the eastern or Sierra Nevada side than in any other part of California, and here and in Utah they committed the greatest ravages. In the southern coast counties they were comparatively few in number and did very little injury. They were more troublesome around Los Angelos than anywhere else in the south.

The Oregon Times of September 29 says: "In the southern part of Oregon, the present season, grasshoppers have been ravaging the country, utterly destroying every green vegetable substance. In certain localities whole nurseries of fruit trees have been killed and entire fields of grain have been destroyed. The grasshoppers infested northern California last year, and seem to be making a pilgrimage through Oregon. This year they have done but little damage on this side of the Calapooia mountains, but are getting quite numerous in Linn, Lane, and Benton counties. They have infested portions of California the past season, sweeping all before them; and in Utah they have destroyed at least one-half of the crops. Fences, ditches, or streams seem to present no barriers to their ravages."

The Great Salt Lake News of 19th September states that "on Thursday, 29th August, several millions of grasshoppers descended on the settlements north of Utah county, destroying everything green in their way. The county of Tooele was visited by a similar plague."

The following extract from a Texas paper (Dallas Gazette, November 20, 1855) will show their appearance in that State. "Grasshoppers are beginning to be troublesome in this vicinity. We hear some of our farmers complaining a great deal of their depredations. Some of the wheat that has been lately sown is completely destroyed, and the fields will have to be replanted. A heavy norther would rid us of these insects."

From the various notices of the visits of the *Locusta* in 1855, made by the periodicals of California, Utah, Washington, and Oregon, it would appear that they are most abundant from the fifteenth of July to the twentieth of September, or a period of sixty-seven days. They would seem also to be at the maturity of their destructive power from the first to the thirty-first of August, which is the hottest and driest month of the year in all these regions.

It may be remarked, in this connexion, that the summer of 1855, and up to the 31st of October, was the driest which has been known for ten years.

The grasshoppers made their appearance again in 1856 in Oregon, Utah, and California, and in Texas, near Austin, and westward, but in such diminished numbers as not to do extensive harm, except in particular localities. But it seems, from the periodical press, that in the upper Mississippi (Minnesota, &c.) they committed great injury in the fall of that year, as the following extract will show: "At Little Falls (says the St. Anthony Express) they destroyed corn, oats, wheat, and every kind of grain which came in their way. At Elk river they appeared in a perfect cloud, and lighting upon a cornfield of twenty acres destroyed the whole crop in a short space of time. At Crow Wing, on the farm of Isaac Moulton, they destroyed five hundred bushels of oats."

Their ravages extended along the first central mesas or steppes, bordering eastward the Rocky mountains, covering the dry soils of Texas, and down into the south of Mexico. In the vicinity of Cordova, in the State of Vera Cruz, the people made "a regular campaign against them, and succeeded in destroying one hundred and ninety-two arrobas, computed as numbering four hundred millions of grasshoppers." In the State of Guerrero they also did great injury, particularly within the districts around Acapulco.

It would seem that the Locusta makes its destructive appearance within the boundaries of the United States Territories, west of the Mississippi, in some portion or other nearly every year. The following extract from a correspondent of the New York Tribune, dated Fort Kearny, August 31, 1857, and who was in the expedition of Colonel Sumner against the Cheyenne Indians of the upper branches of the Missouri, shows the effect of the reappearance of this plague in a strong light:

"The grass along our route has been short and scanty, although refreshed by the recent rains. It is injured by myriads of grasshoppers, some of which are monstrous in size. I have noticed several between three and four inches, and many nearly three inches long. Last Friday a swarm passed over the fort which darkened the sun so as to render it possible to gaze at it with the naked eye. We saw this swarm at a distance of ten or twelve miles, at which it resembled a cloud of smoke."

Every western man remembers the visitation of grasshoppers in 1855 and 1856 in Kansas, Nebraska, and Minnesota Territories, which caused such injury to the crops of the Indians. In the travels of Jonathan Carver, in the northwest parts of the Mississippi and Lake countries, published in 1779, page 494, the following mention is made of the locust or grasshopper: "I must not omit to mention that the locust is a septennial insect, as they are only seen, a small number of stragglers excepted, every seven years, when they infest these parts and the interior colonies in large swarms and do a great deal of mischief. The years when they thus arrive are denominated the locust years."

Since 1823 the grasshoppers have several times ravaged the fields and gardens of the Franciscan missions of Upper California. About the year 1827 or 1828 they ate up nearly all the growing crops, and occasioned a great scarcity of wholesome food. At the

mission of Santa Clara, Padre José Viadere fired the pastures, and getting all his neophytes together made such an awful noise that those which were not killed by the smoke and fires were frightened off so thoroughly as to save the grain crops and the mission fruit gardens. About 1834–'35 occurred another visitation of the grasshopper, when they destroyed a second time the crops of the rancheros and missions, with the exception of the wheat.

An American settler, who resided for ten years near the bay of San Francisco, informs us that in the summer of 1838 the crops and gardens of the missions and ranchos thereabouts were nearly destroyed by the ravages of the grasshopper. Another settler informs us that they committed great ravages near San Rafael, and on the north side of the bay. He saw them eat up, in a single afternoon, a field of thirty acres of beans and peas, consuming it to the surface of the ground. In these districts they stopped for three successive years. A California sea captain informs me that he has sailed through the Santa Barbara channel and neighboring waters when the surface of the ocean was covered for miles with the dead bodies of grasshoppers, the air being filled with them at the same time, and shoals of fish feeding on them.

In July, 1846, a friend of ours living in Monterey was personally cognizant of a field of eight or nine acres on the Salinas plains of corn, frijoles, &c., being completely consumed to the ground in a single day. The appearance of the field afterwards was as if it had been blackened and killed by a heavy frost. The late Mr. J. B. Wall, collector of Monterey, informed me that in a journey from Oregon to Missouri, in 1846, his party encountered in July, on the plains near the north fork of the river Platte, myriads of the grasshoppers, which all appeared to be travelling northward, and proved extremely annoying to the train for many days. Bryant, in his "What I saw in California," relates that on his passage to California, under dates of July, 1846, their company of emigrants also encountered immense swarms of grasshoppers on the prairies near the Platte.

In the "Utah and the Mormons," by B. G. Ferris, on page 149, mention is thus made of the visitation of the Locusta in the Salt Lake country: "The year 1848 was one of privation and suffering, prior to the maturing of the growing crops. Among other discouraging incidents a curious kind of 'cricket' made its appearance in myriads, manifesting all the destructive properties of eastern countries. All vegetation was swept clean before its frightful progress as effectually as the grass before the scorching fury of a prairie conflagration, and the crops, put in with so much toil and on which so much depended, were fast disappearing. Suddenly, however, flocks of white gulls floated over the mountain tops with healing in their wings, and stayed this withering destruction by feasting on the destroyer. The crickets and the gulls have been annual visitors since, as they were before; the bane and the antidote come together." They are said to appear invariably in great numbers in very dry and hot summers, succeeding to very inclement winters.

Throughout California, with its ante-1849 boundaries, throughout Lower California, New Mexico, and all the dry and the elevated

mesas or plateaus of the republic of Mexico, their ravages have been noted by the old Spanish chroniclers from the first conquest and settlement of the countries; also by American trappers, hunters, and travellers throughout the same regions for the last fifty-five years, and by English, Russian, and French writers and navigators. Dr. Dwight mentions that they have several times been extremely injurious to the growing crops of New England prior to 1800.

It would seem that the most feasible means of destroying the grasshopper, or diminishing its propagation and increase, is that which nature and circumstances suggest. The extensive conflagration of the grassy plains and hills of California has been noticed ever since the years 1542–'43, in the account of the voyage of Juan Rodrigues Cabillo, and particularly near San Pedro, (the present embarcadero for Los Angeles,) which he named the Bay of Smoke. The entire range of California, Utah, and Eastern Oregon, and neighboring countries being deserts, prairies, or lands of hills and mountains sparsely covered with trees, and everywhere thickly or thinly with grasses, we know they become excessively dry for three months of the year, when they either take fire from accident or design, or, as is most likely in some cases, from the attrition of the leaves and glazed stalks in a dry and windy day. As soon as the parched vegetation is fired, with a good breeze of wind it will burn an immense district of country before it is stopped by a wide road, a dry river bed, running water, or damp ground. In its progress it consumes all animated nature not capable of speedy flight or escape, and destroys the undeveloped larvae and millions of eggs of the grasshopper, as well as thousands of the full grown insects, whose wings and legs get singed and burnt in trying to make their escape from the devouring element. The wind at times conspires to bring immense numbers of them within the influence of the fire, and so to stifle them as to bring them to the ground. In a strong gale, when swarms of grasshoppers are on the wing high in the air, they are swept along until, as the breeze slackens, they fall into the waters of large bays, seas, and cover large extents of the surface of the ocean, where they become a prey to greedy fishes.

The annual conflagration of our plains occurred this year (1855) very early, which circumstance had considerable effect in destroying the swarms of grasshoppers, as, to escape the heat, they endeavored to keep out of the influence of the fires, and being driven before the winds, were swept into Siuson bay in incredible numbers. The passengers in the steamer from Sacramento to San Francisco, on Saturday, the 14th of July, state that they fell in such numbers into the waters of the bay as to completely cover in places the surface. When driven ashore afterwards with the tides they filled the air with an intolerable stench.

The Indians take the grasshoppers in great numbers by sweeping them into holes or piles, or by surrounding them with fire and driving them into the centre, and afterwards roasting and pounding them for food. But this is always found to sicken the Indians—a fact which has been noted by the pioneer settlers and natives of old, as also by many travellers and voyagers who have visited

California and the Rocky mountain country, and also by the Jesuits of Lower California.

The species found near Monterey, and examined in October, were of a burnt sienna color, one inch and three-eighths long by one-eighth of an inch thick, with three black blotches on each outer wing; the legs are also barred black; the lower body parts of ochreous yellow; the inside wings, which are very thin, are yellowish, with a broad black fringe. The head is of a lighter color than the body, and is as hard as the shell of a peanut. The mouth is armed with two hard, black forceps, nearly one-eighth of an inch long, the inside edges of which are bevelled inwards, finely serrated, and very keen. Four of these October grasshoppers (males and full-grown) weighed thirty grains.

We may note here that the grasshoppers in July around Monterey, where but few came this year, are not more than half the size that they are in October. The species of grasshopper described in Captain Stansbury's journey to the Salt Lake country, in 1850, and figured and described by Professor S. Haldeman, is a species of the Locusta different in size, colors, and particular features from that found near Monterey. Haldeman calls this Salt Lake grasshopper the *Oedipoda corallipes*, and says that it is congeric with the *Oedipoda migratoria* of the English naturalists, and which is found so destructive in Asia Minor and the Crimea. The *corallipes* is nearly as large as the *migratoria*, being two and a half inches long. The California grasshopper, or rather the species found near Monterey, I have seldom seen over one and a half inches long, and it is not in any manner colored "bright vermilion" in any part of its body, as is mentioned by Haldeman of the Salt Lake species. There is only one species of the Locusta described in the above work. It has either no antennæ, or it is faintly delineated. The date of preservation or capture of this *Oedipoda* of Utah is not stated by Haldeman.

The following account from Gage's West Indies, page 368, will show the effects of a visitation of the Locusta in the parishes of Mixco and Pinola, and other parts of the uplands of Guatemala in the year 1632:

"The first year of my abiding there it pleased God to send one of the plagues of Egypt to that country, which was of locusts, which I had never seen till then. They were after the manner of our grasshoppers, but somewhat bigger, which did fly about in number so thick and infinite that they did truly cover the face of the sun, and hinder the shining forth of the beams of that bright planet. Where they lighted, either upon trees or standing corn, there nothing was expected but ruin, destruction, and barrenness; for the corn they devoured, the fruits of trees they ate and consumed, and hung so thick upon the branches that with their weight they tore them from the body. The highways were so covered with them that they startled the travelling mules with their fluttering about their heads and feet. My eyes were often struck with their wings as I rode along; and much ado I had to see my way, what with a montero, wherewith I was fain to cover my face, what with the flight of them which were still before my eyes. The farmers towards the South sea coast cried out, for that

their indigo, which was then in grass, was like to be eaten up; from the *Ingenios* of sugar the like moan was made, that the young and tender sugar-canes would be destroyed; but, above all, grievous was the cry of the husbandmen of the valley where I lived, who feared that their corn would in one night be swallowed up by that devouring legion. The care of the magistrate was that the towns of Indians should all go out into the fields with trumpets, and what other instruments they had, to make a noise and to affright them from those places which are most considerable and profitable to the commonwealth; and strange it was to see how the loud noise of the Indians and sounding of the trumpets defended some fields from the fear and danger of them. Where they lighted in the mountains and highways, there they left behind them their young ones, which were found creeping upon the ground, ready to threaten such a second year's plague if not prevented; wherefore all the towns were called, with spades, mattocks, and shovels to dig long trenches, and therein to bury all the young ones. Thus, with much trouble to the poor Indians and their great pains, (yet after much hurt and loss in many places,) was that flying pestilence chased away out of the country to the South sea, where it was thought to be consumed by the ocean, and to have found a grave in the waters, whilst the young ones found it in the land. Yet they were not all so buried; but that shortly some appeared, which, being not so many in number as before, were, with the former diligence, soon overcome."

Clavigero, in his history of Mexico, says of the Locusta of Mexico, that no animal or insect in that country "can compare in numbers or ravages with the locusts which, sometimes darkening the air like thick clouds, lay waste all the vegetation of the country, as I have myself witnessed in the year 1738 or 1739 upon the coasts of Xicayan, in Oaxuaca. From this cause a great famine was lately occasioned in the province of Yucatan; but no country in America has been visited by this dreadful scourge so often as the wretched California, as related by Father Michael del Barco, who lived thirty years in that country as one of the missionaries of our society."

The same author gives the following interesting account in his History of California:

"For the reason that this plague does not affect the countries where naturalists may carefully observe them with minuteness and exactness, we herein relate the account of one of our missionaries, kept for thirty years, during his residence in the missions of old California.

"There are three species of California grasshoppers, which are similar in form, but distinct in size, color, and mode of living. The first species, which is well known and the best observed, is small; it flies short, but is constantly jumping. The second species is larger, and of a gray color. These two kinds are not found in such numbers as to make them of such note or anxiety as the third, which is the largest, and causes the most destruction in its flights over the lands of the peninsula.

"The grasshoppers of this third species, famous for their ravages among the lands of the missions, is of the size of a little finger; the

wings double like the others, but larger and colored variably, according to their age and sex, which we shall hereafter note.

"These largest grasshoppers are those we shall particularly account for in what we relate. They assimilate in their habits and modes of generation to those of the silk worm. The two sexes come together in the hottest days of the summer season; the female, at the latter part of July or early in August, lays a number of fine, small eggs of a yellowish color, in a string, united with a glutinous matter, which, on being perceived, appears like a cord of fine silk. These are deposited together and dropped into a small hole which they make in the ground with a small apparatus attached to their tails. Each female lays from seventy to eighty eggs, and sometimes more. Shortly after fulfilling the great law of nature, the grasshoppers quickly degenerate and die without taking care of their lives or of each other, but leaving in their eggs the seeds of a numerous posterity.

"The birth of these new grasshoppers has no particular time, but is dependent on the early or late appearance of the rains, but generally hatch during the latter part of September or early in October, when, from the scarce rains of California, the germs and buds of plants are left in the fields. Shortly after birth, while they are without wings, their lower legs are very large but shaped like those of a mosquito; the color of the insect is then a dark gray. Their first exercise is to jump on to the nearest green thing. If there is none near by they keep jumping and moving to the nearest green plant, and generally in company with those of the same nest and mother. As soon as they have consumed the leaves of one plant they pass to another, by little assuming a brighter color, and then the different families begin to unite. When they arrive at half size their color is a perfect green. At this time their legs have become strong and they jump higher and farther, and exercise and contrive the best method for seeking their food while passing along the fields. A few days after assuming their green coat, they cast their skin or outer covering, and then display their four wings which are close shut to their bodies. The color then becomes green, mixed with dark gray. When they are three months old they are complete in size, form, and features, and become of a reddish gray with blackish spots. Its appearance as thus seen is the only beauty of this pestilent plague of California. They maintain these features until the hot, dry weather, when they become yellowish until their death. Their life, from birth to death, lasts ten months, during which they cast their coats twice and change their colors five times.

"When their wings have become of sufficient strength and the body at its maturity, they then begin to ascend into the air and fly like birds, and commence their ravages in every direction, desolating the fields of every green thing. Their numbers become so extraordinary that they soon form clouds in the atmosphere which the rays of the sun cast a shadow as they fly. They unite in masses of ten and twelve thousand, always following their conductors and flying in a direct line without falling behind, for they consume every growing thing before them. To whatever height their guides conduct them to obtain a sight of their food they follow, and as soon as growing crops or any verdure is sighted, instantly the swarm will alight and speedily devour

and devastate the fields around to that extent and with that promptitude that when they are seen by a new swarm of their fellows, there is not anything more left to injure or consume. In the night they neither eat nor sleep, but are all the time mounting and jumping on each other in thick masses, and bending and cracking with their weight the branches of the shrubs and trees they may cover or rest on.*

"This lamentable insect-plague is bad enough in old and cultivated countries, but in the miserable peninsula of California, where they eat up the crops, green trees, fruits, and pastures, they cause great mortality in the domestic animals of the missions, and with the effects of their ravages on the cereal and other garden productions, cause great famines and sickness among the inhabitants and neophytes of the establishments. At one time immense multitudes of these voracious insects died, infecting the air dreadfully with the stench of their corruption and decay.

"The grasshoppers do not generally attack such plants as watermelons and melons, for the reason that such plants have leaves covered with fine pricking hairs. The *pitahayos* are naturally defended with their spires and prickles, and with the other cactus family are not disturbed, except in their flowers and ripe fruit. In the mescal plant they only attack the extremities of the *pencas* without touching the shoot or sprout, which is a species of aliment used by the Indians.

"From the year 1697, when the Jesuits commenced the labor of christianizing the heathens of California, the grasshoppers had not made their appearance in the lands formed by the missions until the year 1722, when they made their appearance, and then ceased until 1746, and for three years immediately following without intermission. After this they did not return until 1753 and 1754, and, finally again, before the expulsion of the fathers in 1765, 1766, and 1767. For many reasons has this unhappy peninsula, for several consecutive years, escaped the affliction of the plague of locusts. Probably in certain seasons their eggs could not be hatched for the exceptions of the fall of ordinary rains, as sometimes here occurs, and also for the abundance or their eggs consumed by the birds. Also, it is stated, that in the spring of the year incredible numbers of the grasshoppers are killed by a certain worm which is engendered in the stomach of the locusts, and which commits great havoc amongst them; for this reason, probably, and others mentioned, and some as yet unknown causes, they have not made their appearance in large numbers in the seasons elapsed between the years mentioned.

"Anciently the Indians of the California missions used the grasshoppers as food, by first toasting them, and, after extracting the entrails, pulverizing them before eating. But the good counsels of the missionaries, after their appearance in 1722, when this species of food occasioned among them a great sickness, caused them to leave off using them, though some of the neophytes still would eat them in the years when food became scarce from their ravages in the sowings."

The following account is taken from the New Notes on Central America, by E. G. Squier, from which it will be seen that the

* This last fact was noted by the nurserymen of Sacramento in 1855.—A. S. T.

Locusta of Central America is nearly if not quite identical with that of California:

"The insect, however, which is most dreaded in Honduras, as, indeed, in all Central America, is the Langosta, or Chapulin, a species of grasshopper or locust, which at intervals afflicts the entire country, passing from one end to the other in vast columns of many millions, literally darkening the air and destroying everything green in their course. I once (in 1853) rode through one of these columns which was fully ten miles in width. Not only did the insects cover the ground, rising in clouds on each side of the mule path as I advanced, but the open pine forest was brown with their myriad bodies, as if the trees had been seared with fire, while the air was filled with them as it is with falling flakes in a snow storm. Their course is always from south to north. They make their first appearance as *Saltones,* of diminutive size, red bodies and wingless, when they swarm over the ground like ants. At this time vast numbers of them are killed by the natives, who dig long trenches, two or three feet deep, and drive the *Saltones* into them. Unable to leap out, the trench soon becomes half filled with the young insects, when the earth is shoveled back, and they are thus buried and destroyed. They are often driven in this way into the rivers and drowned. Various expedients are resorted to by the owners of plantations to prevent the passing columns from alighting. Sulphur is burned in the fields, guns are fired, drums beaten, and every mode of making a noise put in requisition for the purpose. In this mode detached plantations are often saved. But when the columns once alight, no device can avail to rescue them from speedy desolation. In a single hour the largest maize fields are stripped of their leaves, and only the stems are left to indicate that they once existed.

"It is said that the *Chapulin* makes its appearance at the end of periods of about fifty years, and that it then prevails for from five to seven years, when it entirely disappears. But its habits have never been studied with care, and I am unprepared to affirm anything in these respects. Its ordinary size is from two and a half to four inches in length, but it sometimes grows to the length of five inches.

"The crops of maize are often destroyed by the *locusts* in the course of a few hours. As the visitation is usually general, it sometimes results in a great scarcity, bordering on famine, in which case maize advances to as high as four and five and even ten dollars per bushel. Fortunately the insect seldom attacks the fields which are planted high up on the slopes of the mountains, where the people make their *milpahs* during the periodical visitations of the *Chapulin.*"

This statement is consonant with the accounts received from Honduras and Guatemala of the famine and pestilence of fever in those countries in 1855 and 1856, caused by clouds of locusts devastating the country, and confirms Gage's history of the same lands in 1632.

At the time of the visit of Darwin to Chile and the adjacent countries of South America, he relates of the grasshoppers as follows, at the date of March 25, 1835, where he is crossing the dry country which lies between the city of Mendoza, in Buenos Ayres, and the opposite side of Chile. This country assimilates in every essential

physical characteristic to that of the territories within the boundaries of Upper and Lower California prior to the American occupation:

"Shortly before arriving at the village and river of Luxan, we observed, to the south, a ragged cloud of a dark reddish brown color. At first we thought it was caused by some great fire on the neighboring plains, but we soon found that it was a swarm of locusts. They were flying northward, and with the aid of a light breeze they overtook us at the rate of ten or fifteen miles an hour. The main body filled the air from a height of twenty feet to that, as it appeared, of two or three thousand feet above the ground. The sound of their wings was as the sound of chariots of many horses running to battle; or rather, as I should say, like a strong breeze passing through a ship's rigging. The sky, seen through the advanced guard, appeared like a mezzotinto engraving; but the main body was impervious to sight. They were not, however, so thick together but that they could escape a stick waved backward and forward. When they alighted, they were *more numerous than the leaves in the field*, and the surface became reddish instead of green. The swarm having once alighted, the individuals flew from side to side in all directions. Locusts are not an uncommon pest in this country. Already, during this season, several smaller swarms had come up from the south, where, apparently, as in all other parts of the world, they are bred in the deserts. The poor cottagers in vain attempted, by lighting fires, by shouts, and by waving branches, to arrest the attack. This species of locust closely resembles, and perhaps is identical, with the *Gryllus migratorius* of Syria and Palestine."

It is a little singular that though the ravages of the grasshoppers have been noticed by all the presses of California, Utah, Oregon, and Washington, and particularly by those of the Sacramento and Utah valleys, not one of them has given any detailed description of the different species of locusta infesting those districts of country; nor have any of our naturalists or observing writers made more than a passing notice of the animal whose history hereafter will leave the most melancholy marks of its devastation on the means of subsistence of the people who may fill up these territories. If they have been recorded in the annals of Africa, Asia, and Europe, for four thousand years, and have been chronicled in the histories of the Californias for one hundred years, we may be sure that there is nothing to prevent their periodical devastating visits within the boundaries of the North Pacific slope for four thousand years more.

The habits of this insect ought to be diligently observed by the cultivators of the soil in our State. It requires from the State authorities the employment of the best naturalists to study and compile for public use the most searching investigation into the birth, multiplication, and best methods of checking the increase of this terribly devouring and consuming pestilence.

The "California Farmer" of July 5, 1855, says: "The following facts can be relied upon, having been received from such sources as leave no question of their correctness: Wherever the floods covered the soil, and remained a little time, no grasshoppers appear; they rarely or never are found in shaded grounds or damp and wet locali-

ties; they are destroyed by winter ploughing—deep, subsoil ploughing."

The same paper adds: "We have made many inquiries, and from those who have seen and examined their habits we gather the following: The grasshopper's shell, or his decayed body, is found about ten or twelve inches below the surface, in the sandy soil in gardens and orchards. Those who plough early and deep find them turned up in large quantities, and also note that where the soil is ploughed deep and early they do not make such ravages.

"We learn that irrigation at night and showering the trees and vines have, in many instances, driven them away. Heavy shade and awnings serve as means of protection. Grounds that are low and damp, and such as by constant cultivation give forth a dew at night, this insect avoids. Shade and moisture they shun; a hot and dry location they select, and the hotter the day, the more terrible their ravages. The hottest days they move with more rapidity."

There is a bird in India termed the grakle, which is a great consumer of the locusta and its eggs. This grakle, we judge, is similar to our California chenate, or blackbird, which all know is found in the valleys of the Sacramento, San Joaquin, and the coast, as also the Rocky mountain countries, in such immense flocks as often to obscure the sun; they are incredibly abundant at some seasons in the lower part of the Sacramento valley. The inhabitants of India have often killed the grakle to almost extermination, from their injury to young crops; but when this has been effected a great multiplication occurs of destructive insects, and particularly of the locusta, as the following, from Buffon, will show: "Some of the eggs of the locusta being accidentally introduced from Madagascar into the French island of Bourbon, they multiplied so prodigiously as to threaten devastation to the country. But the governor, a man of superior intelligence, learning the great services of the grakle in India, had a number of pairs introduced and distributed over the islands under his charge, which included Mauritius, &c. They bred very fast, and in a few years the locusts seemed exterminated. The grakles then began to dig and examine the newly sown fields; on which the colonists, concluding that they were devouring the seed, when they were in reality seeking the locust's eggs, took the alarm and got them exterminated by government. In a few years they perceived their error, for the locusts soon commenced their ravages again. Upon this the government procured a new supply of grakles, which were given in charge this time to their officers; the physicians being instructed to declare their meat unwholesome food. This extraordinary care, however, proved injurious, as after the birds had cleared the islands of the locusts and their eggs, which infested the coffee plants, the birds began to injure the grain crops and orchards, and even to kill young pigeons and other domestic birds; on which means were taken by the government to keep down their numbers by a measured destruction."

It appears that a species of blackbird, similar to the one of California, is found in immense numbers in Southern Russia, in Poland, the Holy Land, Arabia, Lower Egypt, and the shores of the Mediterranean sea. It is called the rose colored blackbird, (*Pastor roseus*,) and feeds

on grasshoppers, locusts, and their eggs and larva, of which it can devour incredible numbers in a day. It was also observed in the colony of the Cape of Good Hope, by that indefatigable naturalist, Le Vaillant. In the works of the great Aldrovandi, of Bologne, in Italy, (1599,) they are called sea starlings. No doubt they are intended in California to act as a check on the increase of grasshoppers and locusts. The description which Alexander Wilson has left of the red winged starling of the southern Atlantic States, (1810,) agrees precisely with the habits of our blackbird proper, and its companion the dun-colored thrush, as they combine together in immense flocks in the summer and autumn months.

Wilson estimates that two millions of the starling will consume, in three weeks, the enormous amount of sixteen thousand two hundred millions of the eggs and larva of grasshoppers and other kindred insects. The combined ravages of such a hideous host of insect vermin, as Wilson remarks, is enough to spread famine and desolation over a wide extent of cultivated country.

It will thus be seen that in the order of Providence the enormous number of these birds found in California and the Rocky mountain country is intended as a positive blessing, for all time to come, to the people who may make it their home. When these regions become filled up, in the course of two centuries, with a numerous population of herdsmen, miners, and cultivators of grains and fruits, the value of this bird will be keenly appreciated, and no doubt suitable laws will be made for its protection. An old settler informs us that this bird sometimes becomes a great ravager of the grain crops. In the valley of the Pajaro they have appeared in some years in flocks of millions, and have done great injury to the wheat and barley, when the grain was ripening. "This also is an evil," but a much smaller one than the grasshoppers.

It is suggested that collections of locusts, grasshoppers, and their congeners be made by intelligent observers and amateurs living in different parts of the country. The insects should be gathered from the eggs to the grub and the perfect animal. A number of specimens, male and female, should be procured, and this at different seasons of the year. The specimens may be dropped into vials containing alcohol, brandy, rum, whiskey, or any other spirit, without further trouble, and corked up. These should be packed in a small box.

The Smithsonian Institution is making a special study of entomology, and all contributions of the kind transmitted to it at Washington from any part of this country will meet with attention and acknowledgment. It is not out of the way to assert that the generosity of the donors will redound greatly to their credit, to the cause of liberal science, and to a more perfect knowledge of this most celebrated of all insects.

Such a collection being concentrated at one point will wonderfully facilitate exact analysis, and cause to be distributed throughout the world copies of faithful engravings of the different species of the locusta, which can nowhere now be found in the annals of science.

ON THE MEANS OF DESTROYING THE GRASSHOPPER.

BY V. MOTSCHULSKY.

Translated from the Russian by Professor Wm. W. Turner.

The tendency to an equilibrium in all things is a law of nature, and accordingly this law holds good in regard to the locusts.* Whole generations of them succumb to the climatic influences of those countries to which, impelled by hunger, they betake themselves. Winds and storms not unfrequently cast vast swarms of them into lakes and seas, and other millions perish in crossing rivers. Frogs, lizards, and various birds, especially of the starling, blackbird, lark, crow, jackdaw, stork, and other species, devour them with great avidity. Among these is the so-called rose-colored starling, (*Gracula rosea*, L.,) of a shiny black color, with a whitish red back and breast, resembling at a distance our black starling with the coat of a magpie. It breeds in great flocks in southeastern Russia, especially about Orenburg, and throughout Asia Minor, where it is known by the appellation of *samarmog* or *semermer*. As soon as it perceives at a distance a flight of locusts, it immediately pursues them; and in the evening, when the latter alight on the ground, the destroying and devouring begin without loss of time, and continue as long as any remain. According to the popular tradition of the Asiatics, these birds are said to abound about St. James's Well,† on Mount Ararat, and always to follow its water. Accordingly in Georgia and in Asia Minor, particularly in Damascus, Aleppo, and Mosul, speculators sell water from the above mentioned well to be used for alluring the samarmog when the locusts make their appearance. But the inhabitants of those countries now place no great faith in this sympathetic means, but rely in preference on other modes of destruction. In the south of France, according to the testimony of the learned Solier, the common European blackbird (*Turdus merula*, L.) takes the place of our rose-colored starling, and produces great devastation among the Italian locusts. In Africa, and especially in the Isle of France, there is found still a third species of starling, (*Gracula gryllivora*, Daud.,) a cinnamon-colored bird with a blackish head and white belly, which likewise pursues and destroys the locust. In all the places where the birds show themselves thus useful to the inhabitants, to shoot and catch them is regarded as a crime. In ancient Egypt, the ibis was counted sacred, because it destroyed quantities of reptiles and injurious insects, especially locusts. In the south of France one of the birds that destroys the locust is known by the name

* The term "*locust*" used in this article is applied to what is called in this country, the grasshopper. The "*cicada*," or locust of America, is an entirely different insect.

† The well and the monastery situated near it were buried in the year 1840 by an earthquake.

of *gabian*. It appears to be our stork. In the Neapolitan dominions, the landholders on the appearance of the locust place their chief reliance on the birds. In Asia Minor and other southern regions, the locusts make their appearance so frequently and in such vast quantities, that the birds alone cannot meet the requirements of the inhabitants. In North America, the young turkeys are trained to seek out and feed upon the larvæ of grasshoppers and locusts, especially when they begin to hatch from the eggs, whereby great numbers of them are destroyed.

Domestic fowls, as geese, ducks, turkeys, and chickens, are exceedingly fond of such food. About Temeshvar, in Hungary, the locusts were once got rid of by driving into the place where they had alighted 15,000 head of swine, which in a single night and morning devoured them all.

Of insects, the one called the tormenting ichneumon, (*Pimpla instigator*,) of the order Hymenoptera, deposits its eggs in the egg-cases or tubes of the locust; and when the larva comes forth, it sucks out the whole fifty eggs there congregated, so that the case remains empty. This insect, which is also beneficial to forests, by destroying the caterpillars that injure the trees, has a body of a black color with reddish yellow legs. It has four wings, all of which are transparent and veined. Antennæ long. The hinder part of the body is broad, but grows narrower towards the thorax as in the wasp. The female has at the end of her body a long tube and a fork. With the former she lays her eggs, and on the latter she leans when it is necessary to pierce a place in which to lay an egg. The larva of this insect is white, partially transparent, without legs, and resembles in appearance a small worm; when full grown it is about four lines long, and in its narrow head are the scarcely observable parts of its mouth.

Another insect of the tribe of Braconidæ, called the short-winged ichneumon, (*Proctotrupes brevipennis*, Latr.,) has often been found by me near the Italian locusts, on which were traces of bites upon the sides of the thorax and abdomen. Hence I suppose that this insect also stands in some sort of connexion with the locusts, aiding, it may be, in the diminution of the latter. But I have not succeeded in detecting it operating in this manner.

In America a species of mud-wasp attacks the young brood of the locust, and carries them to its nest to nourish its larvæ there. At the same time this strange phenomenon is observed, that the wasp previously seizes the insect which it requires, stings it, and thus produces a paralyzed condition; so that, without dying, it remains in a motionless state, and as it does not putrefy in the wasp's nest, it can serve for food during the whole growth of the larva.

Taking into consideration the means provided by nature for restraining the multiplication of the locust within the requisite limits, we may assume that, of the eggs laid by it about one-tenth succeed in passing through all the transformations of their existence, and with this tenth part alone it comes in conflict with the husbandman. But even this is sufficiently great to furnish matter for reflection to every one who knows by experience what an attack of the locust is. The most

illustrious nations in the world have not disdained to devote their time and means to the destruction of this pernicious insect.

In the Acropolis at Athens there stood a brazen statue of Apollo Parnopius, who had driven the locust out of Attica; but in what way, the historian Pausanias could not learn. In other parts of Greece Hercules was adored for the same reason. Pliny asserts that in Rome, on account of the devastations of the locusts, recourse was had to the Sybilline books. In Syria and Chaldea, the locust was dreaded only about the end of the month of June; because, fearing as was supposed the constellation of the Pleiades, it did not venture to appear until the latter had set.

In some parts of Italy the inhabitants hid themselves in their houses when the locusts appeared, under the notion that they do injury only when attention is directed to them or when an attempt is made to drive them away. In Palestine and Mesopotamia, on the contrary, every one went out to meet a flight of locusts when it came in sight, and endeavored to drive them away with smoke from burning piles of wood, with beating of sticks and rods upon the ground and in metal kettles, with a noise of great musical instruments, shouting *jerād! jerād!* * and such like expedients. In Arabia and Egypt, they also endeavored to frighten the locusts with cries of *samarmog! samarmog!* the name of their terrible enemy the rose-colored starling, at the same time throwing sand towards the locusts, cursing, spitting, and working themselves into a fury, believing the insect to be exceedingly timorous, selfish, cunning, and possessed of Heaven knows what other qualities.

That the locust is timid, is a fact known long ago. Stoikovitsh informs us that some locusts once alighted in a field of ripe grain. The reapers immediately rushed forth, and began to sharpen their scythes, in order to reap the millet. The locusts, frightened at the noise, ascended the stalks, looking about to see what was the matter, and when the reaping began, they flew away.

In Austrian Galicia, in the year 1828, on the first receipt of the news that the locusts were moving from the direction of Odessa towards the frontier, the inhabitants hastened to harvest the grain wherever it was possible. As soon as the insects appeared, the people met them with shouting, noises, and the firing of guns and pistols; and they actually succeeded in driving them off towards the west. An hour afterwards, another flight appeared more considerable than the first; and, disregarding all the noise of the assembled villagers, they began to alight. Everything fell into confusion, and each one hied him to his own field or kitchen garden, so that the noise was diminished. Nevertheless, this flight also was driven into the woods. But an hour later, the enemy's main army made its appearance, and unsparingly seized upon the whole country for forty miles in circumference. The insects were so ravenous, that in a quarter of an hour each one devoured from eight to ten ears; and so numerous, that, in the neighboring

* The Arabic name of the locust.

small town of Konincha, about 29,000 bushels of them were buried in the ground without any perceptible diminution.*

At the time of the flight of the locusts through the passes of the Bukovina, in the year 1780, an attempt was made to destroy them by discharges of cannon. The flight was indeed dispersed in places; but, dividing into several small portions, the whole flew across the Dniester, and some of them alighted on fields in Podolia.

The driving away of locusts on the wing with noises and cries not only does not always answer expectation,† but through the hope of success it renders the people careless. It is also injurious in this respect, that if it saves one cultivator it infallibly exposes his neighbor to loss. Hence people living along the coast endeavor to drive the locusts into a sea or lake; but even this rarely succeeds. Sometimes after they have been driven into a wood, it has been set on fire; whereby greater loss has been occasioned than by the insects themselves. But in these instances the people's dread was so great, that they seemed to imagine that, by extirpating the locust, they would annihilate some sort of evil spirit, hobgoblin, or destructive monster.

Confounding almost everywhere the means of destroying the footed locust with those of defence against the attacks of the winged insect, cultivators commonly complain of the inefficacy of the measures adopted. For this others have been to blame as well as themselves.

In Morocco, where people have been acquainted with locusts and subjected to their ravages at some part of the year time out of mind, it has long been known as a peculiarity of the footed insect to keep advancing in a certain direction. Accordingly, they endeavor to stop its progress by intersecting its line of march with wet or dry trenches, filled with combustible materials, into which the insects are driven. These ditches often serve as aqueducts for inundating their rice-fields. This mode is also known in Algiers and throughout Europe. But as the trenches are in general laid out irregularly, and there is neither time nor means for making them so deep and wide that the locusts cannot leap across them, or climb or swim out, the object is rarely attained. Usually the locusts swim across the water by thousands; and where fire is spread about, in consequence of the great quantity of locusts that are swept down and driven together, it is extinguished, and the insects crawl away.

Others drive into places occupied by the locusts troops of horses, flocks of sheep, and herds of cattle, that they may trample down their uninvited guests. But the locust is nimble; and even were it not so, horses and other beasts trample upon and crush them with reluctance. Landowners, not taking into consideration that the locusts are hardly ever destroyed by such means, and that the men and cattle tread down scarcely less grain than the insects would consume, constantly have recourse to this practice. They do not reflect that, by burning up the

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* This labor was entirely superfluous; because if the locusts are killed and put into a bag, they cannot do any further injury; and by burying them in the ground, like infected garments, we only lose an excellent material for enriching the soil.

† It is known that neither such noises nor the firing of cannon, nor any other power whatever, is able either to stop or drive away large bodies of locusts.

winged insects, for instance, the evil is by no means done away with, but is renewed in a great measure the succeeding year. The locusts, too, are consumed with a great waste of time, labor, and combustible material; whereas they would necessarily die in a few days, and, by copiously manuring the fields laid waste, would in a measure compensate proprietors for the damage they had sustained.

In the province of New Russia the destruction of locusts, in the year 1855, was effected, according to the testimony of Col. Tshernjavski, in the following manner:

In the district of Leoff a commencement was made on the 20th of May,* by digging around the young locusts small trenches connected with the river Pruth. Having partitioned off a space of some 5,400 acres, all the grass was mowed off, and the locusts burnt up with it. Besides this, both morning and evening, in other places where the locusts had accumulated in the greatest numbers, they were trampled down in different circles by troops of horses.† This was done by a draft on the five jurisdictions or townships, consisting of about 705 laboring men per day, who relieved each other for seven days. The Bulgarian colonies also furnished 300 Bulgarians, who worked at excavating the ditches. This activity continued for just thirty days, till the locusts were all destroyed. In destroying the locusts in the Leoff district the inhabitants consequently expended 22,950 days' labor.

In the Bulgarian colonies the same means were used, only with this difference: that, for the more convenient passage of the locusts to the excavated trenches, cross-paths were cleared in the grass with spades and pick-axes. On account of the deficiency of combustible materials, more locusts were crushed here than burnt. This cost the Bulgarian colonies 23,000 days' labor.

In the Tatarbunar jurisdiction of Akkerman district the footed locusts were mostly crushed out with brooms, in which were expended 20,000 days' labor.

In the Olonesh jurisdiction of the same district about 6,000 days' labor was spent in the same way for this purpose.

In the Bender district, in the government of Izmail, and in the German colonies, the same measures were adopted; but the number of laborers is not known. Col. Tshernjavski assumes approximately that, in all these places, more than 80,000 men were employed, to say nothing of the droves of horses and the various vehicles. All this, being done in the height of the working season, had the effect of retarding and diminishing the sowing of spring grains and the making of hay, besides causing the neglect of other farm labors and the accumulation of arrearages to government. Furthermore, although by means of this costly labor a considerable part of the locusts were destroyed, and the hope of saving the remaining grain was for a while indulged in, yet the event turned out quite otherwise. The locusts left behind in various places, having acquired wings, spread themselves over all the fields in such multitudes, that their former diminution, which seemed

* Evidently too late, as the locusts were already sufficiently strong and lively to escape from the danger.

† An exceedingly inefficacious means.

so enormous while their destruction was going on, became quite imperceptible. Each day they alighted on new places, and everywhere produced devastation. Consequently all the labors described were only so much money thrown away, in addition to the losses suffered directly from the locusts, which had then destroyed not less than half of all the grain sown.

If we assume the same ratio for the number of laborers who turned out to destroy the locusts through the whole province of Bessarabia, in the Kherson, and other governments to which the insect migrated, we may boldly assert that more than a hundred thousand working days of the best farming season were spent in destroying them without success.* An immense amount of money was thus completely wasted.

Meanwhile the dread of the locusts was not put an end to. From information collected in the places themselves, it appears that they left their eggs behind them over an extent of 14,426 *desjatins*, or nearly 39,000 acres. Calculating a single egg-sac for every square *sazhen*, (49 square feet,) we obtain 34,622,400 sacs; and at the rate of 50 eggs to a sac, the whole will amount to 1,731,000,000 of eggs.

If a locust during its life time, *i. e.*, in the course of 100 days, will require, on an average, for its support twelve drachms of common grass per day, then the consumption of these insects for the whole of their existence will not be less than 228,000,000 poods, or 3,675,787 tons.

Estimating the value of a pood of grass at one silver kopek, (three-fourths of a cent,) the whole loss sustained by the ravages of locusts in Bessarabia in the year 1835 will amount to at least 2,280,000 silver rubles, or $1,710,000. It should likewise be observed that in making these estimates the very smallest measures are taken, and that grain is reckoned at the same value as grass. After this, it will certainly not appear strange that the locust should be considered a *destructive insect.*

Some have thought to free their fields from locusts by watering them with lime-water or lye. But is it practicable to carry this out to any great extent, and will the fluid fall on the locusts' eggs, especially when they are covered with a coating of earth? In Slavonia, at the close of the last century, for the purpose of destroying the footed locust, which was already crawling about, they made use of wooden harrows loaded with weights, which were dragged about the fields as in harrowing grain. Some of them went obliquely, one after the other, beginning with a large circle; each succeeding time they described smaller circles; and in this manner, advancing in a spiral, they gradually approached the centre. But as the harrow went slowly and could follow only the prescribed course, the locusts easily leaped aside, and the entire proceeding was almost fruitless.

It has been proposed to surround the fields with cords and rods smeared over with tar, to which the locust has a great repugnance. Yet it is scarcely possible to carry this plan into execution, except for very small enclosures.

Lastly, for the purpose of driving the insects away, long ropes have

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* And this, too, because, from want of a knowledge of the habits of the insect, its destruction was commenced too late and without a previous examination of the locality.

been used. These were drawn along the ground, as low as possible, by two men having hold one of each end, who at the same time made a noise by bawling and beating, thus endeavoring to drive them into trenches dug across, or to a linen cloth stretched out upon the ground and drawn up to a ridge, where they were trampled upon or crushed with rollers, or burnt up along with the grass.

Instead of these absurd, unreasonable, and inefficacious means of attacking the locust, we find that, in remote antiquity, the wisest precautions were adopted.

On the island of Lemnos, in Greece, it was ordained that, on the appearance of the locusts, each inhabitant should furnish a certain measure of them to the rural police; and among the Cyrenians it was considered obligatory upon every one to take part, three times a year, in the general destruction of these insects, first, in trampling down the eggs, next in destroying the young larvæ, and lastly in killing the adult locusts. A neglect to obey this ordinance subjected the individual to general contempt, and was punished as disobedience to the laws.

In China it has been the rule from the earliest times to publish yearly, in the Pekin Gazette, the edict of Bogdy-Khan, that all the rural authorities should attend betimes to the destruction of the locusts in order to prevent their becoming a public scourge. The governors of provinces are consequently obliged, in all places situated near the coast,* to assemble the people early in the spring, and distribute them in parties about the known nests of the larvæ of the locust, and see that the destruction of these larvæ is effected in good season, speedily, and in the regular manner. They also distribute to the laborers the established compensation for their work.

In the time of the Eastern Roman Empire, the whole population was wont to hasten forth to the destruction of the locusts. Kerchiefs and sheets were spread out upon the ground under the bushes and trees, and upon these the insects were driven and shaken down. These cloths were then rolled up and twisted hard. In other places they used sacks, into which the locusts were thrown and crushed under foot. At the close of the hunt the whole gathering was weighed, and the Greek patriarch distributed for it a fixed payment. Such a regulation exists to the present day in many parts of Turkey, where, on the appearance of the locusts, the local authorities, for the purpose of destroying them, drive forth the peasants armed with brooms and shovels, especially the so-called *rayas*, or Christian population, who, however, find it difficult to obtain the established reward of four parotshkas the oka.† Some years ago, in a single morning, as many as 8,000,

* It is the common belief of the Chinese, that the locust is engendered in the littoral provinces, by means of the sun's rays, from putrefying fish-roes remaining along the shore after a haul. This absurd theory probably originated in the fact that on the seashore, and about brackish waters in general, great quantities of dead locusts are heaped up, which perish there by reason that, in leaping about the brackish soil, the insects sink into it and the salt sticks to their legs, leaving them unable to free themselves and escape; the next advancing tide drowns them, and casts them up on the shore. The locust is also especially fond of laying its eggs in sandy places overgrown with reeds, where consequently they are hatched.

† An *oka* is about 2¾ pounds.

and in the course of the spring as many as 80,000 okas of the young larvæ were collected in this manner.

In France, when the locusts make their appearance, every one turns out that can—men women, and children, and with whatever is at hand. From the earliest times, by a regulation of the government, a common price has been paid for the locusts collected and also for their eggs. The collected eggs are either buried in the ground or thrown into the rivers.* About Arles, Ste. Marie, St. Jerome, and other parts of Provence, women and children are mostly employed in collecting the eggs; and as the locust breeds there perpetually, its destruction is a task constantly devolving upon the inhabitants.

In Italy likewise a price is paid for collecting locusts, and once, in the neighborhood of Milan, the rural police received not less than 12,000 sacks of them, which had been gathered in the course of a few days.

In Hungary, not only all the people turn out to the locust hunt, but even the domestic animals and fowls join eagerly in the pursuit; and for what is collected a reward is paid by the government. The same is the case in Spain, where, in the year 1780, about Zamora, in addition to the peasantry, the troops were employed in destroying the locusts. They were stationed around the young locusts just hatched, and with long brooms swept them into common heaps, around which fires were kindled. Three thousand men were employed by turns in this work for three weeks, and they succeeded in collecting about 18,000 bushels of locusts, so that each man in twenty-one days caught about six bushels, or a little over nine quarts a day.†

With us in Russia, it was decreed by an imperial ukaz of the 17th of July, 1802, that a sum equal to about a cent a pint should be paid for locusts' eggs collected in Little Russia; afterwards the price was raised to ten cents. On the appearance of the locusts in the province of New Russia in the year 1823, the chief local government appropriated the sum of $75,000; but the amount of private expenditure on this account was not ascertained.

In France, at the present time, a reward of half a franc is paid for a kilogram of the eggs, and a quarter of a franc for the same weight of insects.‡ It is known that in the year 1613 the city of Arles expended the sum of 25,000 francs for collecting 134,000 kilograms (about 295,000 pounds) of eggs and insects. The city of Marseilles spent 20,000 francs in this way in the same year, 5,542 francs in 1824, and 6,200 francs in 1825. In the year 1832, in Ste. Marie alone, 61 laborers collected 1,979 kilograms of locusts' eggs; and in 1833 they gathered 3,908 kilograms; so that one person collected not over 63 kilograms in the course of three months.§

* A very bad practice, inasmuch as the egg-sacs which are cast into the water may be thrown up again on the bank, and, under favorable circumstances, may be hatched.

† A very small quantity, in consequence of undertaking the work too late, namely, when the locusts had already begun to crawl about

‡ As the locust is comparatively light, the price for collecting them in France is hardly less than with us.

§ Or scarcely two-thirds of a kilogram per day; which at least shows how defective were the arrangements for the destruction of the insects, and how inefficient was the mode of collecting.

In order to increase the amount collected and to facilitate the operation, various auxiliary devices have been contrived and put into practice.

It is the custom with us in Southern Russia to gather both the footed and the winged locusts at night with the aid of a sieve, and to throw them into sacks, where they are crushed by trampling upon them or by pounding them with beetles.

In the south of France they use for this purpose a breadth of cloth, which is held at the corners so as to form an inclined plane. By running the cloth rapidly along the grass or grain, the locusts are made to jump or fall upon the cloth, from which they are shaken off into sacks, and then crushed. In this manner, according to Solier, from four to six kilograms of locusts may be captured in a day.

Fig. 1.

In July, 1826, one Arnold Thompson, of New Hampshire, succeeded in catching, in a single evening, between the hours of eight and twelve, five bushels and three pecks of locusts. The contrivance used by him was the following: Having attached together two sheets, he formed of them a sort of bag, which was fastened to a cross-pole, to permit the locusts to enter into the bag, and so that two men could take hold of the two ends of the pole and draw it rapidly along the grain. From these two ends also two braces extended to the back knot of the sack, in order that the hinder end of the apparatus might be held as high as possible above the ground, so as not to break down the grain with the knot. With this apparatus the fields were swept over in the evening, *when the locusts are perched quietly upon the grain*, in such manner that the striking of the ears against the edge of the sheet shook off the locusts into the bag. Bulging out with the pressure of the air, it would not suffer the insects to escape, but all passed on towards the knot. After moving the drag rapidly a dozen rods, the braces were taken out, and the sheets doubled over; the knot was then put into a common sack, and untied, and the locusts poured out. The emptied bag was again tied up, and the catching proceeded. The locusts in the sack were destroyed by plunging it into boiling water.

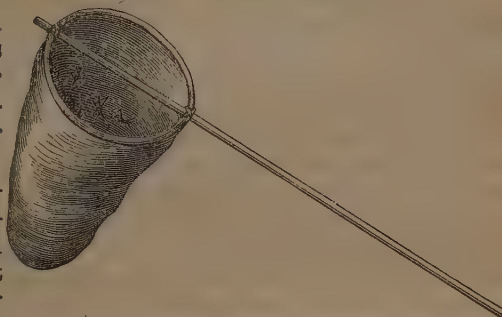
Fig. 2.

In the year 1824 we employed in the Crimea a still more convenient apparatus. To the mouth of a sack three feet and a half in length

was attached a hoop of an elliptical shape. To the two opposite edges of the hoop, at the place of the greatest curve, cords were fastened. Grown persons or children, by taking hold of the cords, dragged the sack along as rapidly as possible, almost touching the ground. The locusts that fell in were trampled on with the feet. The dead insects were then thrown out and the catching recommenced.

Fig. 3.

Fig. 4.



A still better apparatus, employed with great success in the south of France, consists of a sack growing narrower towards the bottom and fastened to a pole in the manner employed by entomologists. According to Solier, an ordinary boy with this contrivance will catch not less than 50 kilograms, which is at least ten times as much as by any of the preceding methods.* This hunt for the wingless locusts is undertaken in May or June.

The American writer, Harris, recommends that all the grass and grain should be mowed in those months in which the young locusts make their appearance, thus destroying them by hunger; inasmuch as at that time they are feeble and unable to migrate far in search of food. Besides, they lose the power of sheltering themselves from the weather, and soon perish from cold and storms.

All the methods described are of incontestable utility, and have often proved so in practice. But unfortunately they are not always carried out with the necessary exactness, at the proper time, and under the circumstances indicated. By reason of the carelessness which seems inherent in so many people, they undertake the destruction of the locusts when they are already, so to speak, at the husbandman's door. No one observes or wishes to observe the place where the locusts lay their eggs in the spring, or the time of their hatching, because then they do no injury. They do not know or care to know how the insects are developed, when they begin their march, or when their flight takes place. Having thus allowed the locusts quietly to breed and develop, they employ too late and without discrimination the above described means, which accordingly prove inefficacious.

In the Appendix to Vol. XIII of the Collection of the Civil Laws of Russia, very useful rules and precepts are given for the destruction of locusts; but few know how to apply them.

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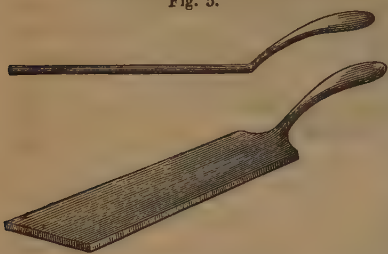
* All these methods are efficacious, if skillful arrangements are made for them; but the places in which this mode of capture is practised are more or less trampled down by the laborers.

For the destruction of the locusts in Bessarabia, in the year 1836, the following measures were adopted by Col. Tshernjavski, on the principle that *the less the locusts have advanced in their growth, the aesier they can be destroyed:*

In the first days when the rye began to shoot into ear, 150 persons, both grown people and children, were despatched into the fields belonging to the villages of Gantshur and Pogoya, of the Bender district. The children were furnished with common *wooden beaters,* shaped like those used by washerwomen, having a blade two feet long, five inches wide, and seven-eighths of an inch thick, with a curved handle ten inches long, and so contrived as to strike with the flat side upon the ground or the locusts. The adults had a sort of shovel with a much longer handle, three feet in length, so as to be grasped with both hands.

Fig. 5.

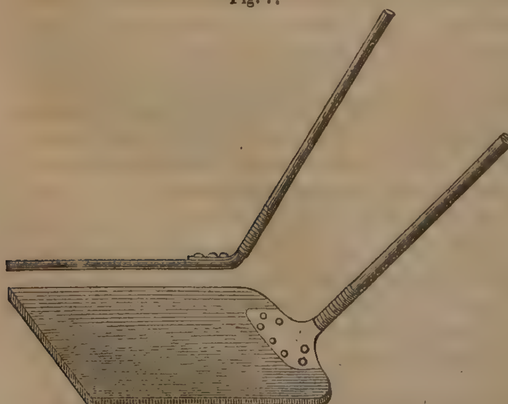


They found the locusts, as yet of very small size, in swarms in the places where they were hatched. The laborers provided with beaters and shovels were divided, under the direction of their superintendent, into parties of twenty, thirty, or forty individuals; and having taken up their positions on the borders of the space occupied by the locusts, they proceeded from the various sides to crush them out, approaching gradually towards the centre, where they thickly accumulated. As the small locusts do not quit their birth-place, the laborers went three times over the same locality. Accordingly, after giving time for those which had escaped to collect into masses, ten or fifteen laborers destroyed in the enclosed space the entire brood without leaving a remnant. In the course of two weeks, with the above mentioned number of 150 laborers, the whole of the locusts were everywhere destroyed.

Fig. 6.

In the district of Olanesh, in the year 1837, forty persons were employed in the same way; and in the course of five days, viz: from the 1st to the 5th of June, the whole brood of locusts were extirpated for the space of nearly three-quarters of a mile, and over seven bushels

Fig. 7.



of insects were collected. In a single hour six youths crushed more than a troop of 200 horses could have done; which could not have been accomplished by three hundred men with brooms after the locusts had attained their growth. A bushel of these small locusts contained so large a number of them, that three weeks later they would have made over a hundred bushels. And for this there was required neither carts and teams, nor troops of horses, nor bush-beaters. Accordingly, for the destruction of the locusts in the Olanesh district in the year 1837, there were expended 200 days of labor, that is to say, twenty times less than in the year 1835; and the *success was complete*, for the inhabitants of these localities affirm that of the locusts of 1837 not one reached the winged state.

From what precedes we are led to the following general conclusions:

1. It is necessary to observe in the autumn,* especially after a hot summer, where the locusts have deposited their eggs, and to accustom persons appointed for the purpose so to do, especially youths and young children, who else would idly run about the fields and meadows.

2. As soon as the labors of tillage will permit, people should be sent out in the fall to collect the locusts' eggs, provided with sharp sticks or hoes for turning up the ground. If the eggs are deposited in the fields or in sandy places where ploughs and harrows can pass, these latter should be made use of. The egg-tubes of the locusts should be poured into sacks, and then measured or weighed, and a suitable reward paid for the amount collected, so as to stimulate the work-people, and especially the children, to busy themselves in this useful labor.

3. All the places where locusts' eggs are found should be ploughed over, if possible, two or three times very late in the autumn, selecting for this purpose rainy and dull days, because the eggs thus turned up and exposed are destroyed by the wet or by the birds of passage which then make their appearance. Special attention should also be given to bare spots in the fields, where not unfrequently great quantities of egg-tubes remain unobserved.

4. If, after a hot summer, the fall and winter are equable, it will be necessary to repeat in the spring the search for the brood hatched from the eggs that have survived the winter; because this sort of weather is uncommonly favorable to the complete and uninterrupted development of the insect.

5. Since the Italian locust is hatched from the egg much earlier than the Asiatic or migratory insect,† as soon as the rivers break up intelligent persons should be sent every year without fail to examine all the places where the locusts usually come forth, so as not to lose the opportunity for destroying them which presents itself when they sit together in swarms. For the discovery of every such swarm of insects that have not yet begun to crawl about a suitable reward in money should be offered.

6. If the locusts are hatched and their swarms discovered, the boys

* Beginning in the month of August.

† All the methods of extirpation here described are applicable to the Asiatic as well as to the Italian locust; with this difference only, that they must be applied at the time when each species makes its appearance.

and girls of the village should be immediately sent out under the superintendence of some grown persons, the former provided with the *beaters* represented in fig. 5, and the latter with the *crushing shovels* in fig. 6, and with sacks or bags for holding the dead insects. The crushing shovels may also have a straight handle made movable in a vertical plane, it being fastened to the blade by means of a piece of leather, which is nailed on to the blade and is bound to the lower end of the handle by a cord. The blade should be so fastened to the handle, that when one takes hold of the latter with both hands, the whole lower surface of the blade can readily be brought flat down upon the ground.

These shovels may be made in the shape of *fly-flaps*, such as were used in former times for killing flies on the walls of apartments, which consisted of a handle, to the end of which was nailed a small piece of pretty stout leather. In our shovels the leather of the fly-flaps is replaced by a board or blade. Such an implement has this advantage, that the handle, in consequence of its mobility, can be bent vertically, and the man standing over the blade can crush the young locusts with his whole weight. It will not be difficult for people sent out in this way to crush out the whole brood of locusts without leaving any behind, and that in a short time.

7. A few days afterwards people should be despatched again to the places where the locusts were, in order to ascertain whether any of the brood remain uncrushed; and if they have actually escaped destruction and have begun to crawl about, or have set out on their march, it will be necessary to drive out to such places the hogs and domestic fowls, as turkeys, geese, ducks, chickens, &c. Children, also, with bags attached to a hoop and fixed to the end of a staff, as represented in fig. 4, can be sent to catch the locusts by sweeping the bags over the grass and grain as a mower swings his scythe. This, however, should not always be done in the same direction; they should be instructed, wherever the locusts are found in the greatest numbers, to sweep alternately to the right and left. Having made about ten sweeps, let them turn the ring over, so as to close the bag and prevent the locusts that have fallen into it from escaping. These are to be emptied into larger bags or sacks, and then crushed by pounding with pestles, as shown in fig. 8. The children should be rewarded by a payment in money for a successful catch. By repeating this sort of hunt after the footed locusts one, two, or more days, according to their growth, number, and greediness, the grass trodden down by the children has time to recover, and in a short time the insects are all caught, notwithstanding their almost infinite numbers. It should also be observed that breed-

Fig. 8.

ing large quantities of domestic fowls, and especially training them betimes to feed on young locusts in the places where the latter are often found, is exceedingly advantageous to the husbandman. The training of goslings, chickens, and young turkeys to feed on young locusts is to be effected not at once, but gradually, by the poultry-keeper, who should present at first one or two locusts in the crumbled food of the young fowl, and increase the quantity by degrees by the addition of living as well as dead insects. The breeding of large numbers of Guinea-fowl, (*Numida meleagris*,) which multiply rapidly in the steppe cantons of the Caucasus, would have the effect of diminishing the swarms of locusts; since this bird is all its life constantly running to and fro, and would vigorously pursue the insects.

8. All the locusts which are thus collected and killed or crushed can be profitably employed in manuring flower or kitchen gardens and fields; for after they are crushed they cannot breed or do any further injury, and they constitute an excellent fertilizer.

9. If the locusts have already nearly reached their full growth, and the inhabitants and proprietors in their vicinity have not taken notice of the fact, it will be necessary to watch them with double vigilance, in order to surprise them in the act of assuming the winged form, at which time they are uncommonly feeble and sluggish. It will then be found very advantageous to drive out troops of horses, all the horned cattle, and the swine, into the places where these tender and pale-colored insects are to be found, for the purpose of trampling them down.

10. If the insects should fly to a distance, and settle anywhere in a thick mass, it would be well to send out people to the spot in the evening with heavy rollers, made of timber, fixed on iron or wooden axles and drawn by horses or oxen. They should be made sufficiently heavy, of logs nine or ten inches in diameter, and about seven feet long.

Fig. 9.

The locusts, wearied with flying about, and having eaten their fill by the evening, sit at night, and especially towards morning till sunrise, quietly and closely; so that the roller when drawn among them crushes multitudes, and thus one's neighbors' fields, if not one's own, are preserved. By not permitting the locusts to lay their eggs, the proprietor can indulge the hope that in the following year his crops will escape. I regard the providing of these rollers in districts infested by the locusts as a public necessity, as in some cases they can also be usefully employed against the so called earth-worm.

11. Besides the rollers, the use of bags fixed on hoops, as in fig. 4 or 3, will be found advantageous, according to whether the grass and grains are to be preserved or whether they may be trodden down, which again will depend upon their degree of ripeness. The hunt should be commenced at sunrise and continued until the morning dew is dried up, after which the locusts become too brisk in their movements.

12. It is necessary to exercise caution in driving out these insects from grass or tilled fields when the grain is already green but not ripe; because such places, even after being visited by the locusts, are sometimes able to recover and to furnish some sort of a crop. But when they pass over fields of corn after the grain is more or less ripened, there is no means of saving it.

13. No one can be prohibited from driving away the locusts from his field; but it should no less be the duty of the elders of the villages to see that the expulsion of the insects is performed by the united efforts of the community, and not to the injury of any one proprietor. But to observe this is very difficult, and the scaring away of the insects is only permissible where there are large uncultivated wastes or forests, lakes or seas, to which the swarms of locusts can be driven.

14. As we have useful institutions for securing against losses from fire, from hail, from shipwreck, and the like, it might not be without advantage to have a means of insurance against locusts, in the shape of *municipal moneyed corporations* and *banking institutions*, established in the principal cities of those portions of Russia which are subjected to their ravages. Each inhabitant of the region indicated might make a very small annual payment, and in this manner a capital would be accumulated sufficient to indemnify those who have suffered loss, and to recompense such as have distinguished themselves in collecting and destroying this pernicious insect. Supposing, for example, that the region of southern Russia which is subjected to the visits of the locusts has twenty millions of inhabitants, and that each paid into the treasury of the insurance office only *one cent a year;* this, for the first year, would give $200,000, and in ten years, together with the interest, would amount to over *three million* dollars. The payment to sufferers by way of indemnification should be in proportion to the frequency with which the locusts made their appearance in a place, and to the amount of damage occasioned by them.

15. It may therefore be said, in conclusion, that the most effective and at the same time the easiest mode of opposing the development of the locusts is the crushing out of the young broods when collected in swarms in the place where they were hatched. Consequently the most important thing is to know the nesting-place of these destructive pests. In order to discover them and to point out the course to be pursued by the inhabitants of the villages in their vicinity, it might be well, in the first place, to send skillful persons to these localities to make the necessary researches ; and these, with the assistance of the local elders, might seek out the places where the insects abound, and establish the necessary regulations for their destruction.

VEGETABLE COLONIZATION OF THE BRITISH ISLES, OF SHETLAND, FAROE AND ICELAND.

BY CH. MARTINS.

[Translated for the Smithsonian Report from the "*Archives des Sciences Physiques et Naturelless.*" Geneva, June, 1848.]

Whether each plant be a native of the place where it is actually reproduced, or whether there have existed centres of creation from which vegetables have been progressively distributed over the surface of the earth, are questions which seem likely to divide, for some time to come, the opinions of naturalists. But while those who suppose the plant to have originated in the locality where we find it treat the problem somewhat vaguely, those, on the contrary, who admit the fact of vast vegetable migrations, similar to those of the races of mankind, and who apply to these questions the ideas furnished by geology respecting the past, and by terrestrial physics and meteorology respecting the present condition of the globe, are not content to see in the geographic distribution of species a fact without premises and without consequences. They seek to discern therein the trace of the later revolutions of our planet, and the action of those numerous and varied forces which still continue to impede or promote the dissemination of plants. They strive to trace upon the map the march of those vegetable hosts which have overrun certain countries, leaving others to retain their primitive flora. Such studies date from yesterday; but reflective minds will scarcely fail to presage their importance. In effect, the creation of existing vegetables has followed close upon the emergence of continents and islands, being in some sort the last act of the geologic history of our globe. Still later, man makes his appearance and tradition commences.

Botanists have long remarked that certain islands have a flora peculiar to themselves, while others afford no plant which does not equally appear on the nearest continent. The British islands are of this class; but we shall not limit our consideration to England, Scotland and Ireland, we shall attempt to follow the vegetable migration through that archipelago of larger and smaller islands, which, under the names of Orkneys, Shetland, Faroe, and Iceland, form the only chain which connects middle Europe with northern America.

Turning our attention first to the botanical geography of the British isles, we have for our guide the ingenious labors of Mr. Hewett Watson* and Mr. Edward Forbes.† Both have carefully explored their

* *Remarks on the geographical distribution of British plants in connexion with latitude, elevation, and climate*, 1 vol., 8vo., 1835; and *Cybele Britannica*, vol. 1, 1847.

† On the connexion between the distribution of the existing fauna and flora of the British isles and the geological changes which have affected their area, especially during the epoch of the northern drift.—(*Memoirs of the geological survey of Great Britain*, vol. 1, p. 336.

country; the former as a botanist, the latter as a zoologist and geologist. One important, indeed capital, fact gives the result at which they have arrived, namely, that the British isles present not a single plant exclusively their own, and which, with one sole exception, is not found likewise in continental Europe. The exception is the unique species *Eriocaulon septangulare,* a native of North America, which has been cast on the shores of the Hebrides. The British isles, then, cannot be considered a centre of vegetation, since the plants which inhabit them exist more abundantly on the European continent. But all have not come from the same regions, and we shall be able to distinguish with Messrs. Watson and Forbes a series of vegetable migrations which have colonized in succession the islands referred to.

Asturian type.—Thanks to the mildness of its winters, Ireland has preserved for us, so to say, the remains of a peninsular flora. We find growing wild in the southwest of this island a dozen plants, natives of the Asturias, which have maintained themselves in Ireland like the last representatives of a colony whose point of departure is to be found in the north of Spain. Limited to the western coast, these plants do not exist in the eastern provinces of the island. Farther on we shall seek with Mr. Forbes to discriminate the probable causes of that migration, the most ancient of all, since it supposes a temperature and a distribution of lands and seas very different from those which exist at present.

Armorican type.—The southwest of England and southeast of Ireland present a vegetation whose analogy, with that of Brittany and Normandy, has long attracted the notice of botanists. Many southern species are to be met with along the western coasts of France, up to the point where the steadily increasing rigor of the climate arrests their migration towards the north. A certain number of these plants find, in the peninsula of which Cherbourg occupies the extremity, so mild a winter temperature that they maintain their ground in spite of the heat of the summers. These have afterwards spread themselves in the southwest of England, along the coasts of Devonshire and Cornwall, whence they have gained the opposite shores of Ireland and have become naturalized in the counties of Cork and Waterford. It was thus that the Normans formerly passed from the same region, under the conduct of William the Conqueror, to invade England. But the vegetable occupation has never penetrated beyond the south of the island, and the rigors of the climate which could not arrest the progress of the men have opposed an insuperable barrier to the invasion of the plants.

Boreal type.—The mountains of Scotland, Cumberland, and Wales offer to the botanist a vegetation entirely special, and different in all points from that of the plains of England. Analogous to the vegetation of the Swiss Alps, this flora presents a still more striking resemblance to that of the arctic countries, such as Lapland, Iceland, and Greenland. The greater part of the plants which subsist on the summits of the high mountains of Scotland vegetate at the level of the sea in the islands of the Frozen ocean; but there are many of them which have never been recognized in the Alps of Switzerland. By far the greatest number, however, of these vegetables exist at the

same time on the shores of the polar countries and on the snow-crowned summits of the Alps of central Europe.

Germanic type.—It is this which predominates in England, and constitutes, as we may say, the basis of its vegetation. Natives of the north of France and of Germany, these plants have occupied the greater part of England, Scotland, and Ireland, as heretofore the Saxons invaded the territories of the Angles in order to supplant them. If it be true that the aboriginal owners of the country disappeared after the invasion, it is thus, perhaps, that the plants of Germany have stifled those which formed the primitive vegetation of these islands. In the course of ages the Germanic type has become so predominant that most English botanists designate it by the name of the British type. Nevertheless, a certain number of plants pertaining to this type have never traversed the strait which separates England from Ireland, while the rest of the migration transcended this obstacle. Species common on the English coasts of St. George's channel are unknown on the opposite shores of Ireland. The investigations of the geologist have confirmed in every respect the inductions derived from botany. Certain animals which occur indiscriminately in Germany are in the British islands emparked, as it were, and restricted to the region where the Germanic flora exclusively prevails. Thus the hare, the squirrel, the dormouse, the marten, the mole, are limited to England, and do not appear in Ireland. In the latter island five species alone represent the class of reptiles, while eleven occur in England, and twenty-two in Belgium, the point of departure for the Germanic migration. The living molluscs, such as the different species of Helix and Clausilia, are distributed in like manner.

The maritime fauna and flora obey all the laws which control the distribution of terrestrial vegetables and animals. Certain kinds of marine algæ proper to southern climates occur only on the western coasts of England, where also certain species of fish are caught, which never pass beyond the straits of Dover and St. George's channel. These are the neptunian representatives of the Asturian and Armorican types. In like manner the herring, the cod, the pollack, abound only in the North sea, along the eastern coast, where the Germanic type is predominant. Finally, the great Cetacea, such as whales, narwals, and dolphins of the Arctic seas, seem even in the depths of the ocean to respect the ideal limit which separates the boreal vegetation of Scotland and of England from the more southerly floras of Cornwall and the south of Ireland.

Till the present time naturalists had seen in this distribution of organized beings, with reference to certain definite regions, but a natural consequence of the all-powerful influences of climate and of soil. If some plants of the Asturias maintain themselves in the south of Ireland, it was thought a sufficient explanation that they find there the temperate winters of the Iberian peninsula, while the moderate heat of the Irish summer suffices for the ripening of their seed. For a like reason the plants of Brittany and Normandy have established themselves in Cornwall and Devonshire, where a climate prevails analogous to that of their own country. The robust growths of Germany had found in the middle region of England, in the south of

Scotland, and the north of Ireland conditions of existence analogous to those of the north of Germany and of France, and hence their multiplication and diffusion through the larger portion of the British islands. Lastly, the crags, the heathy acclivities, the peat-mosses and moors of Scotland, afforded to Arctic plants the diversified stations, the summers without excess of heat, the long winter slumbers, and the protecting snows of polar regions.

Mr. Edward Forbes could not content himself with these explanations; he discerned a deeper meaning in the existence of those foreign types which constitute the fauna and flora of the British islands. To him they seemed to present vestiges of an order of things which has passed away; proofs of the existence of climates warmer or colder than those now prevailing; signs of a configuration of land and sea whose traces lie hidden in the depths of ocean. We may be permitted to follow him in his ingenious and learned researches. Penetrating first into this new path, he may, he must have often gone astray. But with a powerful grasp he re-unites the past and present of our globe, he summons every realm of nature to the support of his ideas, and even though he may be mistaken, he will not the less have contributed to the progress of the natural sciences by commencing the overthrow of that imaginary barrier which scientific inquirers as well as tradition have reared between the actual state and the geologic epochs of our planet.

The dozen plants from the Asturias, which inhabit the southwest of Ireland, are in the eyes of Mr. Forbes the remains of the most ancient vegetable colony of the British isles. Of all the plants they now sustain none are more completely strangers to the soil which bears them. The remoteness of the continental point of departure, the vast gulf which separates the little colony from its mother country, the difference of climates, the small number of surviving species, all announce an ancient origin and an order of things entirely different from that now existing. Mr. Forbes, ascending through the series of geologic formations, transports us to an epoch when the last tertiary deposits were formed at the bottom of a sea which covered a great part of the south of Europe and the north of Africa. The existence of that sea is proved by the numerous fossil shells of identical species which are found at a multitude of points from the isles of Greece to the southern districts of France. When these newly formed lands lifted themselves above the sea they formed a vast continent, embracing Spain, Ireland, a part of the north of Africa, the Azores, and the Canaries.

The upheaving of the bottom of that sea is not a gratuitous hypothesis, since Mr. Forbes has found these same shells in the Taurus, at the height of 6,000 feet above the level of the Mediterranean. Yet more: the vast bank of floating algæ which extends in a half circle beyond the Azores from the fifteenth degree to the forty-fifth degree of latitude, retraces for us, perhaps, the outline of that lost continent. Its shores have disappeared beneath the sea, but the cincture of marine plants which girdled it still floats on the surface of the waters.*

* This bank is composed of a species of algæ, the *Sargassum bacciferum*, which appears to be only a floating variety of the *Sargassum vulgare*, which is found attached to submarine rocks bordering the coasts of Europe.

According to Mr. Forbes, the appearance of Armorican plants in Devonshire, Cornwall, and the southeast of Ireland, connects itself with the existence of this vanished continent. The southern physiognomy of these vegetables strikes him as indicating a milder climate than now exists; yet nothing forbids our considering this migration as cotemporaneous with the Germanic inroad, if we refer it to the period when France and England were not yet separated.

The immersion of this great continent was followed by a very dissimilar era, during which the temperature of the air was lower than at present. It was during this period, according to Mr. Forbes, that the migration of Arctic plants, which still cling to the mountains of Scotland and England, took place. The proofs of a glacial era, immediately preceding our own, abound throughout the north of Europe. I shall not speak here of the numerous traces of ancient glaciers, observable in the mountains of England and Ireland, but restrict myself to arguments drawn from the animal kingdom.*

The larger part of the British Islands is covered with a moveable deposit formed of transported materials, which the English geologists have designated by the name of *drift*. In two-thirds of England and Ireland lying towards the north, and throughout Scotland, this drift contains the remains of animals which are no longer found alive except in the depths of the Frozen ocean, on the coasts of Iceland and Greenland. Their enumeration would detain us too long. I shall content myself with instancing the right whale, the cachelot, (sperm whale,†) the balænoptera, the narwal, a fish of the seas of Greenland, and a large number of shells which are still seen existing in those latitudes. During this period, then, England was in part covered by waters whose temperature was similar to that of the frozen ocean. Not only the plains, but also the lower parts of the mountains, formed the bed or the borders of that ocean; for in Wales beds of gravel, sand, and shells, are found at an elevation of 1,476 feet above the level of the sea. At that epoch England and Scotland, instead of a continuous territory, presented but a group of large and small islands. The mountains of Scotland, Cumberland, and Wales, alone raised themselves above the waves. A climate analogous to that of Iceland prevailed in this archipelago; the summits of the mountains were covered with eternal snows like that of Hecla, and numerous glaciers descended along the valleys to the borders of the sea. The plants of Greenland, Iceland, and Norway, borne by the currents or transported by the floating ice, drifted on these islands, where they met with a climate but little different from that of their native home. This transportation of plants by drifting ice is no gratuitous hypothesis. Navigators of the polar seas have often encountered ice fields loaded with an enormous mass of mingled sand and gravel, on which plants were vegetating, as on the median moraines of the glaciers of the Alps, and which being stranded on some distant coast would there deposit the plants which afterwards spread themselves in the country.

These Arctic vegetables, Mr. Forbes tells us, have not disappeared

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* See, on this subject, "Researches on the glacier period and the ancient extension of the glaciers of Mont Blanc from the Alps to the Jura.—(*Revue des deux Mondes*, tome XVII, p. 919. March, 1847.)

† This species is not confined to the northern seas.—*Translator.*

from England. They still exist in the mountains of Cumberland, Wales, and, above all, of Scotland, where they find a climate analogous to that of their native regions.

At the end of the glacier period the British isles began to rise slowly from the bosom of the waves. Everywhere we observe on their acclivities, terraces or lines of ancient coast indicative of intervals of repose which have interrupted this gradual elevation. To comprehend properly this phenomenon, it is necessary to figure to one's self, not a simple upheaval of the shores, the submarine tracts remaining immoveable, but a simultaneous movement of both, rising proportionally above their ancient level. This upheaval it is which has modelled the existing outline of the British isles and determined the configuration and the depth of the surrounding seas. The depressions have become less profound and the higher grounds have emerged. Hence a change in the maritime fauna. The sea being warmer, its shores have been occupied by the species which now people them. But the change of temperature being much less sensible at great depths, the animals of the glacier period have been able to subsist in that situation. Thus, says Mr. Forbes, in depths where the sounding-line announces from 525 to 656 feet, the dredge brings up the molluscs of the Arctic seas, and even a large number of shells which exist in a fossil state in the *drift* or deposit of the glacier period which covers the northern portion of the British isles. From this assemblage of facts Mr. Forbes concluded that the profounder seas of Britain conceal populations which have existed there since the glacier era, in like manner with the plants which crown the summits of the Scottish Alps.

During the whole of those two geological eras which we have just been considering England, was united with France. The British channel and straits of Dover did not exist. It is an admitted fact in science, concerning which all geologists are agreed, that the separation of England from the continent is an event comparatively modern and perhaps cotemporaneous with the human race. Messrs. Constant Prevost and d'Archiac have perfectly demonstrated it; the former by pointing out the correspondence of the strata of chalk in both banks of the channel, the second by demonstrating the identity of the congeries of rolled pebbles which overlies the chalk. This latter mass, similar to that of our present rivers and streams, forms the most superficial of the deposits, which was consequently formed after all the rest. And as it is the same on both sides of the channel this layer must have been deposited by the same current when the two countries were still united. The separation took place later, occasioned, it would seem, by the removal of the beds of chalk, which on either side dip landwards and have an elevation towards the sea.

At the dawn of the present era England, then, formed a peninsula similar to that of Denmark. The climate and the surface of the country were what they now are, and the plants of France and Germany soon occupied the lately emerged lands. The hardy growths of northern Europe possessed themselves of the greater part. Forests as dense as those of Germany then covered the hills of England. Stagnant waters collected in hollow places, and the mosses and fens

which have replaced them still present to our view the bones and horns of gigantic deer and the buried remains of those primeval forests. Lost species of the ox, the bear, the wolf, the fox, were the sole inhabitants of these solitudes. The task of nature was finished; that of man was to commence. On his appearance the forests fall beneath the axe, the stagnant waters are drained with extended culture, the animals disappear and the human population increases; the features of nature are transformed under the incessant progress of civilization. This transformation, the triumph of human energies, is as complete and profound as that wrought during the geologic cycle when the present era succeeded to the glacier period.

In summing up the ideas of Messrs. Watson and Forbes respecting the origin of the flora and fauna of the British archipelago, we may say with them, that these islands have been colonized by several successive acquisitions from continental Europe from the period of the mean tertiary deposits to our own era. When a vast continent stretched from the Mediterranean regions to the British isles, the plants of the Asturias and of Armorica peopled the south of England and Ireland. To that period succeeded the glacier epoch, during which the land was immerged to the height of about fifteen hundred feet. This was the epoch of the migration of those Arctic plants which still inhabit the summits of the Scottish mountains. When the land emerged anew England was united to France, and the temperature was what we now find it. At this time the great Germanic incursion took place, displacing, to a great extent, all the others, and leaving but scattered vestiges of their existence. Thus, while the Asturian plants are reduced to a few species confined to the southwest of Ireland, the robust progeny of the north finish their conquest, and possess themselves of the soil which is destined at a still later date to become the heritage of a race of human invaders issuing from the same regions. The colonization completed, England is separated from the continent, and this last geological incident, so insignificant in comparison with those that preceded it, has exercised an immense influence on the destinies of the world. Less isolated, England had been less distinctively characterized; her stalwart races might, perhaps, have been confounded with one of the great continental nations from which they sprung.

While Messrs. Watson and Forbes were pointing out the continental origin of the plants and animals of England, I was engaged in studying the vegetable colonization of Shetland, Faroe, and Iceland. These islands form, so to speak, a continuous chain, stretching from the northern extremity of Scotland to the eastern coast of Greenland. I had visited Faroe in 1839, and was struck with the character of its vegetation. Though lost, as it were, in the midst of the Northern ocean, its flora appeared composed of very familiar plants, most of them indigenous to the plains of middle Europe; others inhabitants of the Swiss Alps; some of Scotland and of Greenland. Extending my researches to Shetland and Iceland, I found that these islands also have no vegetation peculiar to themselves, but that all their plants are natives of the continent. The same result had been reached by Mr. Watson in his researches into the Britannic flora. Here a

new problem presented itself: Did these vegetable colonies come from Europe or America? A great number of plants being common to both the Old and New World, the question presented some difficulties. I found, however, more than a hundred species exclusively European; all the others were common to Europe and America. Europe, then, must have had the greater share in the colonization of these archipelagoes; a great vegetable migration had advanced across England and Scotland, the Orkney, Shetland, and Faroe islands, as far as Iceland. Some species had come directly from the coasts of Norway. But, in the mean time, in an opposite direction, the Arctic plants (natives of Greenland) had propagated themselves across Iceland, Faroe, and Shetland, to the mountains of Scotland, where they found a second home. This double migration is evident from the proportional number of the different plants; for if we calculate that of exclusively European plants which enter into the flora of Shetland, we find it to be a fourth, that of Faroe but a seventh, and, finally, that of Iceland but a tenth. Thus, as we leave Europe behind us, the number of plants of its peculiar growth proportionably diminishes; but, at the same time, that of the plants of Greenland origin increases in very nearly an inverse ratio.

Though entirely agreeing with Mr. Forbes as to the fact of the colonization of the isles of the northern Atlantic, I hesitate before adopting his bold and novel hypotheses. Without interrogating the remote past, I find in the action of existing causes a plausible explanation of the transportation of seeds from a continent to the nearest islands, and from one island to another, from England as far as Iceland.

A great current (the *gulf stream*) takes its source in the Gulf of Mexico, follows the coast of America as high as Newfoundland, and then traversing the Atlantic bathes the western shores of Scotland. It is this which conveys thither the seeds of Mexico, still retaining their germinative faculty; it is this which has cast on the shores of the Hebrides the *Eriocaulon septangulare*, a species belonging to North America, and the only one of the British plants which is not also European. In coasting the shores of Scotland the gulf stream collects, doubtless, the innumerable seeds which the water courses bear into the sea, carries them northward with it, and strews them along the friths and shallows of Shetland, Faroe, and Iceland. This current appears to me the principal agent in disseminating the plants of Europe among these islands, and hence the predominance of the European flora over that of North America.

The winds, those aerial streams, play their part also in the diffusion of species, but, like that of the marine currents, it evades all direct observation. Whoever has once experienced those long and terrible storms of wind which sweep the northern seas can hardly doubt their efficiency in transporting from one island to another light seeds, often furnished with down and membranes, which facilitate their suspension in the air. A recent fact gives additional force to this conjecture. The 2d September, 1845, at nine in the morning, there was an eruption of Hecla in Iceland. On the 3d, cinders fell in the most southern of the Faroes, and the same day were wafted to Shetland, the Ork-

neys, and were observed on the decks of vessels sailing between England and Ireland.

There is another mode of transportation peculiarly incident to the countries we are considering, and which I do not remember to have seen noticed. I allude to birds of passage. Every spring millions of maritime birds leave the coasts of Spain, France, and England, and emigrate northward to lay and hatch their eggs on the solitary cliffs of Shetland, Faroe, and Iceland. The autumn following they return to Europe with their broods. These birds transport rapidly from isle to isle the seeds of plants preserved in their crops or attached to their feathers. They become in like manner a principal instrumentality in the American migration, for it is precisely at the close of the summer of those regions, when the seeds are at maturity, that they return towards the south. In these voyages the islands we speak of serve for resting places, where they deposite the seeds which they have transported through the air.

When we reflect that these united causes have been acting incessantly from the commencement of our era, that is, for thousands of years, it is impossible to cast a doubt on what must have been the prominent effect of such prolonged agencies. Before ascending, then, through the series of geologic ages to explain the distribution of organized beings over the surface of the earth, it would seem obvious that the insufficiency of existing causes should be first demonstrated. And this method is applicable to all the problems of geology. Heretofore, during what might be called the theologic period of that science, it was too much the custom to launch into the most extravagant suppositions. According to the exigencies of the case, sudden revolutions, overwhelming catastrophes, colossal forces, unknown agents, and fantastic causes were pressed into the service. At present, inquiry, having become more sedate, seeks first the reason of geologic facts in the powers of nature acting within the limits which they observe according to our own experience, and enters not the field of hypothesis without having first exhausted that of reality.*

ON THE CAUSES WHICH LIMIT VEGETABLE SPECIES TOWARDS THE NORTH, IN EUROPE AND SIMILAR REGIONS.

BY MR. ADOLPHE DE CANDOLLE.

[Read before the Academy of Sciences of Paris, December 13, 1847, and translated for the Smithsonian Institution.]

It was said by Linnæus a hundred years ago that "all real knowledge is founded on specific knowledge." And, in effect, in all the branches of natural history, a thorough knowledge of species is the

* The causes which M. Martins has assigned above have doubtless had their influence in regard to the flora of the islands in question, but they are not sufficient to explain the peculiarities of the fauna of those regions, and do not, therefore, essentially militate against the hypothesis of Messrs. Forbes and Watson.—*Translator.*

basis on which we must always rest. Nobody disputes this with regard to the work of classification, and experience proves that the same is the case as respects the study of the geographical distribution of organized beings.

Having been occupied several years with the subject of botanical geography, I have often had my attention recalled to a fundamental problem, which will serve to explain many others in the same science. This problem is to ascertain in what manner and after what laws species are arrested in their geographical expansion, and this in the simplest of conditions, on the surface, namely, of a continent apart from the consideration of any mountains which may traverse it. It is easy to conceive that the determination of the boundaries of species must draw after it that of their proportion according to families in each country, and that it connects itself with important questions in physiology and agriculture. It is clear, also, that geologists and physicists require to know to what extent the presence of the same species at two epochs or in two countries determines the analogy of climates, and with what degree of precision the geographical limit of a species proves an equality in the exterior conditions of temperature.

The questions which arise out of this subject have almost always reference to the limit towards the north, or to speak more exactly, to the polar limit or that lying towards one of the poles. I leave out of consideration, therefore, all that relates to the southerly limit.

On the subject of the polar limits opinions have changed with the progress of physical geography. Originally nothing but the mean annual temperature of climates was observed; and on comparing the limits of species with this standard singular anomalies presented themselves. In 1815 and 1817 M. de Humboldt introduced into physical geography an important principle, viz: the comparison of lines passing across the points which offer the same mean degree of temperature during the year, the three months of winter, and the three of summer, being the lines we term isothermal, isochimenal, and isotheral. This illustrious scientist taught us that the mean temperature of seasons is of more importance than that of the year, and that, in general, two similar climates may be distributed into fractions very dissimilar, and which neutralize one another in the estimate of the mean annual temperatures. From this we might judge that the temperatures of seasons or monthly temperatures would explain the habitat of species, or in other words, that each species advances over a continent to a certain line which marks an equal temperature during some period of the year, unless it should be arrested by a climate too dry or too humid, or by a material obstacle, such as the sea. I have believed and have heretofore said,* that annual species ought to be limited very nearly according to isotheral lines, because their vegetation is confined in whole or in great part to the three months of summer. It has seemed to me that the perennial or ligneous species ought often to be limited to the lines of equal temperature during some months of the mild season, or by the comparative shortness of the winters when the question regards plants

* *Geographical distribution of alimentary plants.* Bibl. Univers. de Geneve. April and May, 1836.

which are more than usually sensitive to cold. The assiduity with which botanists have considered this subject of a thermometrical mean shows that more or less they have regarded it in the same light. It has been the custom to attribute the disagreement between the limits of plants and the lines of equal temperature to errors of observation on the locality of species, to uncertainty respecting the thermometric mean, or to causes acting independently of temperature, such as dryness and humidity. But certain facts and the ingenious calculations of M. Boussingault* on the heat requisite for culture in different countries, have awakened some doubts as to the truth of this, and I have been induced to attempt the solution of the question by a direct method. The following is the course which I have pursued:

I have so far investigated nearly forty species as to feel no doubt of any importance with regard to their polar limits. These species have been solely chosen with a view of avoiding causes of error, and of having, at the same time, plants of different nature. Hence I have selected species having their limit in Europe, inasmuch as Europe is the only region where the local flora is numerous, and where the conditions of temperature are well known. I have eliminated all the cultivated species, all species easy to confound with others, all which might have escaped the observation of the authors of local floras, as well as those in which synonyms might have occasioned embarrassment. I have centred my researches on a dozen annual species, a dozen perennial, and a dozen ligneous. I have established their polar limits by means of a great number of floras and catalogues, by the inspection of herbals, and also by questions addressed to botanists residing in some of the less explored parts of Europe. I have succeeded in tracing on the map the limit of these species. I have afterwards consulted the most complete tables of the monthly temperature and seasons of European cities, such as those of Kämtz, Berghaus, Mahlmann, and Dove, completing them by means of private researches.

The following is what results at first view from this comparison, founded on well ascertained facts:

1. In no case does the limit of a species exactly coincide with a line of equal temperature for any one period of the year.

2. The limits of annual species, in the plains of Europe, cross one another with considerable frequency. The limits of perennial and ligneous species also cross each other in different directions, and both are far from being parallel when they do not thus cross.

This single fact enables us to perceive how much the lines of vegetation differ from the lines of equal temperature; for if we draw lines founded on the equality of heat, at a certain season, they will be found to vary little from parallel lines; if we take some other season such lines will still appear nearly parallel with one another, though different, without doubt, from the preceding. Thus, the isochimenal lines will cross the isotheral ones, but they will never cross each other at least in a level country.

A little reflection will teach us that it would be chimerical to pursue the comparison of vegetable limits with the lines of equal tempera-

* Boussingault, *Economie Rurale*, II, p. 659.

ture, at least in Europe and in all countries analogously situated. According as the climate of any locality is more or less excessive, that is, more or less different from one season to another, the vegetation of a plant commences and finishes at different epochs of the year. The lines of like temperature relate to fixed periods, and the vegetation of any one species in Europe lasts during periods which are variable. There can then be no agreement between these two classes of fact, unless by some special accident.

In arriving at the law which governs the limitation of species, I have been led to dwell upon two principles, the truth of which is admitted by all agriculturists and botanists, but whose combined effect had until now received no adequate attention.

It is plain that a great heat during a short period must produce the same effect on plants with a less degree of heat during a longer term. The cultivators who would force or retard plants do nothing but combine the duration and the degree of heat. They thus succeed in producing the flower or the matured fruit at a given day. M. Boussingault has given these facts in a precise form by showing that, for the greater part of our cultivated annual plants, when we count the number of days that the culture has continued, and multiply that number of days by the mean temperature maintained, we arrive at the same product for each culture in all countries and for all years. The heat acts then proportionally as regards its duration and its force. But M. Boussingault has not presented the result of his calculations under so general a form, and in this he was right. There is, in effect, a second principle, which modifies the one in question, and which is of equal importance, at least in botanical geography.

This second principle is, that each species requires, for each one of its physiological functions, a certain minimum of temperature. Not only is any temperature below zero useless to plants, on account of the congelation of its juices, but even those of 1°, 2°, and 3°,* are useless to a great number of species, and ought not to be computed among the temperatures available for the plant. Cultivate wheat, for instance, under a temperature constantly below 4°, though the plant will live long, and the product of the number of days by the temperature reach a high number, yet the stalk will not grow tall nor will the flower be formed. M. Ch. Martins has said, with truth, that each species of the vegetable kingdom is a kind of thermometer which has its own zero.† We should be wrong, then, to infer that 10° during ten days would have the same effect on all plants as 5° during twenty days. In both cases the sum of atmospheric heat is expressed by 100°; but for species which do not vegetate below 6°, for example, the amount of 100 must be diminished by all the values between 5° and 6°, which occur in one of the supposed cases, while for those species which do not vegetate below 10°, if any such exist, the available heat would be reduced to 0. If we would estimate the heat really useful to a species we must consider, in our calculation, only the values above a certain degree of temperature, which varies according to the species. Direct observation seldom permits of our verifying the min-

* These degrees are centigrade.
† *Voyage Botanique en Norwege.*

imum necessary to each species for each of its functions, but botanical geography will furnish us the means of doing so, if, as I propose to demonstrate, the limits of species depend at the same time on the quantity of heat and the minimum required for each species. And here I enter on a field which has not hitherto been explored.

An example will enable us to comprehend how the two principles of which I am speaking combine in European climates, and bring about a similitude or dissimilitude to which the means ordinarily employed furnish no key.

London and Odessa are certainly not under the same lines of temperature. The mean of summer heat is at London 16°.7, at Odessa 20°, while in winter the difference of the mean is much greater. In their monthly mean these two climates have no analogy. Notwithstanding, if we consider the time at which the temperature of 4°.5 commences and terminates in each of these cities, and the product which represents the heat between these two limits, we find the same figure. At London the mean of 4°.5 commences the 17th of February, and terminates the 15th of December. Between these two periods the figure expressing, according to the process of M. Boussingault, the heat received, is 3431°. At Odessa the temperature of 4°.5 commences later, from the 2d to the 3d of April, and terminates sooner, from the 17th to the 18th of November, but as it is warmer during summer, the amount of the temperature between those limits is almost equal to that of London, for it is 3423°. Hence a plant which would require 4°.5 to commence vegetating with a certain activity, which should arrive at the same condition, and would require in all an amount of heat of 3430°, might advance in a northwest direction to London, and in a northeast to Odessa. If a plant should require more or less than 4°.5 as a minimum, or more or less than 3430° in the whole, the climates would no longer correspond, and the limit of species would be otherwise established.

This shows us how two European climates, which differ when considered as regards their respective mean monthly temperature, may yet be identical under certain combinations of the two causes which exert an influence on the life of species. For the purpose of discovering these correspondences of climates I have calculated for a certain number of the cities of Europe on what days the temperature of 1°, 2°, 3°, &c., up to 8°, commences and ends. I have placed over against this list the product indicating the heat received over and above each of those degrees in all the localities. The application of these figures to the facts of vegetation is highly satisfactory, notwithstanding certain sources of error impossible wholly to avoid. I shall here cite but two examples.

The Alyssum calycinum is a cruciferous annual, which grows here and there on the eastern coast of Great Britain and as high as Edinburgh, and even a little beyond, as far as Arbroath. It is found neither on the western coast of England nor in Ireland, nor yet in Brittany or Calvados; but this must be attributed to the constant humidity of those regions, for the Alyssum calycinum prefers a dry region, and it

is evident that it is not heat that is wanting in Brittany to a plant which grows in Scotland.

On the continent the Alyssum calycinum spreads to the northwest as far as Holstein and the Baltic, on the northeast as far as Moscow, but not to Kasan. The limit in the quarters where its extension may be thought to be determined solely by temperature stretches, therefore, from Arbroath, in Scotland, under the 56½ degree of latitude, passes along the 54th degree in Holstein, and thence oscillates in Russia between the 56th and 55th degree. I shall not stop to show in detail how much this line varies from any isothermal line, isotheral, or other founded on equality of temperature. Comparing only the two extremities, Arbroath, in Scotland, with an annual average of 8°, Moscow of 4°.5, Arbroath with a summer average of 14°, Moscow of 17°.8, it will be seen that the mean of each month varies strikingly. I consult my table of the correspondence of climates, and I find that at Kinfauns, in Scotland, very near Arbroath, the temperature of 7° or upwards continues from the 18th of April to the 31st of October, and that during this time the product of the number of days by the mean temperature amounts to 2281°. At Königsberg the temperature of 7° and upwards is of shorter duration, but the summer being hotter, the product amounts to 2308°. As the limit of the species is about twenty leagues to the north of Königsberg, that figure must be reduced, and becomes identical with that of Scotland. At Moscow the mean of 7° commences the 22d of April, and terminates the 5th of October; the product, in consequence of the heat of summer, rises to 2473°. This is more than seems necessary to the Alyssum, and I am induced to believe that it may live thirty or forty leagues to the north of Moscow, but there is no local flora to furnish the assurance of it. At Kasan, the figures fall to 2196°, so that it is not surprising that the species there disappears. Thus the hypothesis of 7° of initial temperature and of a product of 2280° to 2300° accords completely with the facts.

I shall cite another example derived from a ligneous species.

The Euonymus europæus has for a limit the north of Ireland, Edinburgh, (56½ deg. latitude,) the north of Denmark, the south of Sweden, (57—58 lat.,) the isle of Aland, at the entrance of the Gulf of Bothnia, (60 lat.,) Moscow, Pensa, (52 lat.) This limit varies 8° of latitude. In its course the mean annual temperatures vary 4°, the mean winter 12°.7, and the mean summer 3°.4. Those from March to November, which are more conformable, still vary to the extent of 1°.5, and the species, moreover, disappears at several points where the mean of this period of the year is overpassed. The average from April to October and of each other period of the year does not coincide more closely. It is necessary, then, to renounce this mode of explanation. But an hypothesis is at hand which accords with all the facts. The Euonymus europæus requires a product of 2480° between the two epochs of the year when the curve of mean temperature ascends above 6°. In effect this product at Edinburgh is 2482°. In Sweden the city of Stockholm is situated beyond the limit, the product there being but 2268°. St. Petersburgh, with a product of

1894°, is likewise beyond it. The isle of Aland, where, as we are told, the species grows, may well have a more elevated figure than the neighboring cities of Stockholm and St. Petersburgh, in virtue of the influence of the sea, but we possess no observations as to this point. At Moscow the product exceeds somewhat the supposed condition, being 2524°; but probably, also, the species advances a little toward the north of that city at a point where express information again fails us. Finally, it is not found at Kasan, and here also the product is only 2250°. The values then found along the limit, in its neighborhood and beyond it, accord as nearly as could be desired in such a matter with our double hypothesis of 6° and 24 80°.

The chartreux pink, (Dianthus carthusianorum,) a perennial species, is arrested at the west by humidity, but from Koningsberg to Kasan, where its limit depends upon temperature, it is requisite that the plant should receive 2450 degrees between the day when the mean of 5 degrees commences and that when it terminates.

When hypotheses of this character are thus verified successively in many separate cases, and when they repose moreover on incontestable principles of physiology, it may be assumed that they correspond with a law of nature.

That law may, in the present case, be enunciated in the following terms: *Every species having its polar limit in central or northern Europe advances as far as it finds a certain fixed amount of heat, calculated from the day when a certain mean temperature commences to the day when that mean terminates.*

The apparent exceptions to this rule may be explained by two circumstances, which restrict its application.

1. Many species, even in our temperate or northern climates, are influenced as to a portion of their limit by humidity and dryness more than by the conditions of temperature. Those which shun the dryness have a limit inclining from the northwest to the southeast—the eastern part of the continent being the dryest. The species which shun humidity have a limit inclining from the northeast to the southwest, because the more humid regions are, of course, those lying toward the ocean. These causes often determine the west and east limits of species. Quite frequently the same species will be found limited to the east and west by circumstances of this kind, and to the north by the operation of the law above stated. In calculating therefore the figures deduced from temperature, we must ascertain the point at which the limit ceases to be regulated by one of the accessory causes and falls within the control of the law of temperature.

2 The perennial species, and, above all, the ligneous ones, are sometimes arrested towards the north by the absolute minima of temperature. The limit inclines in this case from the northwest to the southeast, because the intense cold prevails most in the interior of the continent. In tracing a limit of species from west to east, if the law as stated ceases to be applicable, the species may be regarded as having encountered the action either of severe cold or of drought; and it is often difficult to discriminate which of these two causes operates as an

obstacle. We can only mark on the map the point where, the usual law ceasing to apply, one of these two causes begins to act.

While the effect of temperature on species was sought for only in thermometric averages and the minima of winter, it was impossible to explain why a great number of the species stop precisely in those parts of Europe where the mean temperatures differ least at great distances. Of this, Scotland is the most striking example. A multitude of species have their limit near Edinburgh; to such an extent indeed that the flora of the country beyond the Grampian mountains has always been considered rather an appendage of the floras of Lapland and the Shetland Isles than of the British. Yet the mean of temperature, compared month by month, differs surprisingly little from one extremity of Scotland to the other. The law above stated enables us to understand these facts. Precisely because of the uniformity and slight variability of mean temperatures in Scotland, there elapses a long interval of time between the day when the temperature of 4°, for example, commences, and that when the temperature of 5° begins. If, then, two species are organized in such a manner as to commence actively vegetating—the one at 4°, the other at 5°—the first will receive for a length of time a heat which is useless to the other, and consequently their limits will diverge considerably. It is not the same under an easterly climate, where the transition from 4° to 5°, 6°, and so on, takes place so rapidly that all species begin to vegetate nearly at the same time. Hence, in the west, the limits are influenced especially by the initial and final temperatures necessary for each species; in the east by the sum total of heat.

The examples on which I have relied are drawn from plants of the centre and north of Europe. I have no doubt but that in countries analogously situated, whether in Asia or North America, we should find the same facts with regard to other species. It would only require that those regions should be as well known as Europe to enable us to verify in detail both the temperatures and the limits. More to the south dryness and humidity seem the principal causes of the limitation of species. Besides, when the temperature operates it is in those regions much more uniform and much more proportional from one season to another, in all localities similarly situated, which is the reason why the average of the year or the season is competent to replace the complicated law which governs species. Indeed, on the borders of the Mediterranean sea, the limits have appeared to me so often determined by the humidity, or by causes still unknown, that the operation of the temperature has almost always eluded my calculations.

The law with which I have been occupied has its application no doubt to the limitation of species as regards altitude. It will show why it is that species do not observe the same relative distances on the flanks of different chains of mountains; why, in other words, the limits of height cross one another in the same way with the limits on the surface of a continent.

It is also probable that by means of this law we shall be able to explain the periods of flowering and maturing for species in different localities

and different years; but in this regard we must expect to encounter in its application difficulties arising as well from the nature of the facts to be observed as from the variableness of the years.*

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* For the epochs of vegetation, as for heights somewhat considerable, and for polar regions, a circumstance touching the manner of calculating temperatures will render the application of the law rather difficult. In thermometrical averages the figures below 0°, are made to enter as negatives; now, it would be necessary, in order to appreciate the action upon plants, to regard them as nought, without retrenching anything from the values above 0°, 1°, 2°, &c. A species which would manifest the effect of a heat of 1°, might vegetate in a season when the mean should be greatly below 0°, according to the ordinary mode of calculation. It would suffice that the thermometer has been above 0° for a certain number of hours. This consideration has prevented me from taking for a subject of study species which have their polar limit in Iceland, Lapland, and under other very high latitudes. The meteorological tables give the monthly averages calculated by subtraction of the negative values; and even when the observations are given in detail, it is difficult, and often impossible, to know during how many hours in a month the thermometer has been above each of the degrees. I solicit the attention of calculators to this point.

Finally, it will be incumbent on zoologists to examine whether the law we have given does not regulate the limits of certain descriptions of animals; of those especially which are hatched from eggs, or which recover from a hybernating torpor at certain temperatures, and which thus require, I suppose, for the total of their active life a certain amount of heat. Zoology and botany having always made a parallel progress, it is seldom that a law discovered in one of these sciences does not immediately receive its application in the other.

As for the relations which connect botanical geography with geology, they become every day more numerous. Perhaps geologists will take pleasure in seeing that the mode of action of temperature upon actual species may be stated with precision. Let them permit me, in closing, a reflection concerning the islands which lie in the neighborhood of the European continent. It has occurred incidentally in the course of my researches. If it presents no new results, which I do not know, it will have at least the advantage of resting on facts foreign to geology itself.

As regards the British isles, the actual limits of the species which I have examined always admit of explanation from meteorological causes, without the material obstacle of the sea appearing in the least to influence them. The limits are not the shore of the ocean; but if a species is wanting to the British isles, it is wanting also to the opposite and neighboring coast, especially to Brittany, the climate of which is nearly similar; if it exists upon the shores of the continent, it exists also in England. We may conclude from this, either that the seeds have been transported without difficulty across the Channel, which is not probable for most of them, or rather that the arm of the sea has been formed within the existence of the actual species. We know that this opinion has been recently maintained by Mr. Forbes, who explains after an analogous manner certain relations between the British islands and remoter countries, such as Spain, the Azores, Lapland, &c. With regard to the islands of the Mediterranean sea the facts are different. I might cite several cases in which it is impossible to explain the presence or absence of a species on meteorological reasons. Thus, according to the observations, rather imperfect it is true, of M. de la Marmora, the south of Sardinia presents the same conditions as regards rain and monthly temperature with certain parts of Sicily; yet many of the species of Sicily are wanting to Sardinia and *vice versa*. The chamærops humilis grows in Sardinia and at Villefranche near Nice; it fails in Corsica, which is between them. In general, notwithstanding certain evident analogies of vegetation, the islands and peninsulas of the Mediterranean offer numerous anomalies in the limits of species. It would seem that this region had been disturbed by many successive geological revolutions since the existence of the vegetables of our epoch, and that the accidental transportation of seeds had been, to this day, insufficient to bring about a conformity between the limits and the climates.

ON THE DISTRIBUTION OF THE FORESTS AND TREES OF NORTH AMERICA, WITH NOTES ON ITS PHYSICAL GEOGRAPHY.

BY J. G. COOPER, M. D.

[This article has been prepared at the expense of the Smithsonian fund for the purpose of illustrating, in connexion with the meteorological observations now in progress under the direction of this Institution and the Patent Office, the climate of the continent of North America. A favor will be conferred by any person who may furnish materials for extending or correcting the list of trees herewith appended.]

The list appended to this article has been prepared in order to show the present state of knowledge of the distribution of the most important and useful trees and shrubs of the country, and at the same time to elicit further information on this interesting subject.

With these objects in view, it has been attempted to give, where known, the extreme points to which each species extends in every direction, and at the same time to show in what part of the country it attains its greatest development and abundance. The chief deficiency in the first part of the plan has been found to be the want of precise localities in the limits mentioned by botanists. For instance, a tree may be described as found in Virginia, and yet not occur for hundreds of miles in travelling through that large State, which includes parts of three very distinct botanical regions. *Any* positive locality is of more use in determining range than such statements as the foregoing, for it enables botanists to increase the known range by observations in their own districts. The various State collections and reports have given the most accurate information on this subject, but very much is still wanting, and, in fact, respecting the range of most trees east of the Mississippi, scarcely anything has been added to the published observations of the two Michaux.

In regard to the region of greatest abundance, there is much of the same want of accurate knowledge. In some cases it has been necessary to judge of this from the nature of the country and the known preference of the tree for particular kinds of soil, or its ability to withstand cold. Although there is much uncertainty on this subject, it will probably be found that the chief facts now known are stated; since I have, at least, good authority for the occurrence, if not for the abundance, of each tree in the region where it is considered most characteristic. Thus, in the absence of statistical information, it was necessary to select for the Mississippi region: 1st. Trees of the swamps, which have their central or maximum of number and development in such a locality. 2d. Such as extend scarcely north of Georgia, and, presumptively, are more common in the warmer region near the Gulf of Mexico. The trees believed to be peculiar to any region have

their name (abbreviated) in small capitals in the last column. The character (?) prefixed to a locality indicates doubt whether this or some allied species is really the one attributed to that place.

Future information may lead to the addition to the general lists of some trees included in the lists of trees nearly peculiar to Florida and Mexico, or to the contrary change. The numbers and letters prefixed to the names are intended to refer to charts of the distribution of trees, now in course of preparation. As trees do not form a natural series distinct from other plants, and as size does not serve as a criterion for their separation from shrubs, it might be considered more scientific to have included *all woody plants* in this catalogue; but as that would have swelled the list entirely beyond bounds, I have made a selection, guided first by the size, and secondly by utility, independent of size. It may be advisable in future to add to or to omit some of the species. Thus, as to the grape vines, *Prunus maritima* and *Cerasus pumila*, I included these and a few more woody plants, not properly trees, for various reasons. Some of the vines grow a foot in diameter, and are of use for wood as well as fruit. The others are interesting as analogues of trees, growing under peculiar circumstances. They may, too, become worth cultivation for fruit; and one of my objects was to include all such as far as possible. The species of *Crataegus* and *Prunus* mostly come under this exception.

The reason for giving the *maximum* heights is, that it is thought the cultivation of trees will become some day a matter of national interest, and I wish to show what they are under the best natural circumstances, supposing that, with cultivation, they will at least equal this standard. Some of the western plants are little more than shrubs; but as the western regions are comparatively poor in trees, I have stretched the limit a little there, since shrubs become more valuable where trees diminish in number.

Nearly all the varieties mentioned by various authors are given; because, first, the difference between a species and a permanent variety is scarcely definable; second, because they are often as truly characteristic of botanical regions as the species themselves. In this article *Populus canadensis* is separated from *P. monilifera* for example, because Michaux could not identity the latter east of the Mississippi; and we look upon it as belonging rather to the Rocky Mountain than to the Apalachian province.

As Michaux notices a difference in the beeches of Canada and the more southern United States, we preferred (as in the other supposed varieties) to consider them as species having distinct ranges, until enough good specimens can be procured to determine the fact. It is doubtful whether there are any trees extending entirely across the continent, within the limits of the United States, which are not more properly included among those of the Lacustrian or Mexican provinces.

Collections of the leaves, fruits, bark, and wood of our native trees are particularly desirable, and from as many localities as possible, in order to determine both their range and abundance, and also to decide those knotty points as to true specific distinctions, which still perplex

the most skilful botanists. The specimens from each tree should be kept carefully together, and the name of the locality and collector given in full. Without such collections no information as to the large genera of oaks, hickories, magnolias, and, in fact, most others, can be at all depended on or made use of. Collections from the extreme corners of the United States, and from any part of the western mountains, will be particularly useful in determining all these questions. A good way of preserving a complete set from each species of tree is to obtain two pieces of the thick bark of the trunk about a foot square, *taking care not to rub off the mosses or lichens*, which are often very characteristic of the tree. Other specimens of bark from the branches, sufficient to show all its changes in appearance, and twigs with leaves, flowers and fruits, may be pressed between the trunk bark, with sufficient paper of any kind intervening, to absorb all moisture. One change of this paper will usually be sufficient, (especially if the bark is dry;) and fruits, if large and hard, may be so fixed as to hang outside, wrapped in paper. Particular care is necessary to prevent mixture of specimens. Blocks of wood from the trunk and branches at various seasons are also desirable for experimenting upon.

Observations as to the relative abundance of each tree at the various stations may be expressed numerically, thus: very rare, 1; occasionally met with, 2; not uncommon, 3; common, 4; very common, 5; abundant, 6, &c.; using numbers up to 10, and explaining them. Frequently several trees will be found so nearly alike in abundance as to require the same number. Notice should also be made of the nature of the country and soil—whether mountainous, rocky, gravelly, sandy, or swampy, which will help to determine the limits of the natural regions. The geological structure of the district is, however, of secondary importance.

The columns of range may be used by observers filling the blanks or adding to the recorded range in either direction; but this must be done carefully and with a perfect knowledge of the species noted. The name of the county should be given as well as of the town, and is preferable if only one is stated. Such blanks, filled up, may be cut out and sent to the Smithsonian Institution, addressed to the Commissioner of Patents, with the writer's name. Meteorological observers will take a special interest in the subject, and in most cases can make the best notes from their habit of observing the connexions of peculiarity of climate and forest growth.

In the annexed catalogue generic and *general* English names are in capitals. The most important synonyms are given in *italics*, as well as local or little-used English names.

The following is a list of the principal authorities consulted in collation of the facts regarding the distribution of trees of the United States, and in the preparation of the map:

Michaux's Sylva.
Brown, Trees of America, vol. I.
Torrey and Gray's Flora of North America, vol. I, II.
Gray's Botany of the Northern States, ed. 1857.
Lewis and Clarke's Travels, (Pursh Botany.)
Long's Expedition. Botany by Dr. James, Say and Torrey, in Ann. Lyc. New York.

Pike's Expedition to Rocky Mountains in 1808, 1812.
Pacific Railroad Explorations, vols. I to VII, and Reports on Botany by Drs. Torrey and Gray, Newberry, Antisell, Bigelow, Cooper, and Suckley.
Collections in Smithsonian Institution from Nebraska, Kansas, California, Oregon, and Washington Territory, and other regions west of the Mississippi river.
Hooker's Flora Boreali-Americana, 2 vols. quarto.
Fauna Boreali-Americana, preface, by Dr. Richardson.
Darlington, Flora Cestrica.
Emerson, Trees and Shrubs of Massachusetts.
Lapham, Plants of Wisconsin.
Hoy, Trees of Wisconsin.
Wailes, Agriculture and Geology of Mississippi.
Kitchell and Cook, Geology of Cape May county, New Jersey.
Thompson, Natural History of Vermont.
Ray Society Reports on Botany, 1849, including Geyers' Notes of Journey across North America.
Agassiz, Lake Superior. (Narrative by J. E. Cabot.)
Torrey, Botany of New York.
Swallow, Geology of Missouri, 1st and 2d Reports, (list of trees.)
Hayden, Trees of Nebraska, in Warren's Explorations, 1859.
Elliott's Botany of Southern States, 1824.
Russell, Climate and Agriculture of United States, 1857.
Richardson's Journeys in Search of Franklin.
Reports on Botany.
Darby, Botany of Southern States.
Geyer, Botany of Oregon, in Hooker's Lond. Jour. Bot.
Gray, (Asa,) Statistics of Flora of Northern United States, in Sill. Jour., 2d series, vol. XXII, 1856, and XXIII, 1857.
Anderson, Synopsis of North American Willows, from Proc. Amer. Acad. Arts and Sciences IV, 1858.
Rafinesque, Florula Ludoviciana.
Trans. Amer. Phil. Soc., 2d series, vol. 3, Dr. Pickering on Distribution of Plants of United States.
Ibid, Nuttall on Plants of Arkansas.
Lieutenant Colonel Kearny and Major J. D. Graham, Top. Eng., East Boundary of Texas, with detailed maps, 1840.
Brevet Captain J. C. Frémont, Top. Eng., Explorations, 1842, 1843, 1844.
Major W. H. Emory, Top. Eng., Explorations of, 1846, 1847.
Lieutenant J. H. Simpson, Top. Eng., Canadian river and Navajo country, 1849.
Captain H. Stansbury, Top. Eng., Exp. to Salt Lake, 1849, 1850.
Lieutenant Colonel Johnston, Top. Eng., Explorations in Texas, 1849, 1850, 1851.
Captains Sitgreaves and Woodruff, Top. Engs., Boundaries of Creek country, (36° 30′, devlled maps,) 1850, 1851.
Captain L. Sitgreaves' Expl. Zuñi and Colorado rivers, 1851.
Captain R. B. Marcy, U. S A., Expl. of Red river of Texas, 1852.
Lieutenant G. K. Warren, Top. Eng., Explorations in Minnesota and Nebraska, 1855, 1856, 1857.
Major W. H. Emory, U. S. A., Survey of Mexican Boundary, 1849, 1850, 1852, 1853, 1854, 1855.
J. R. Bartlett, U. S. Comm., Survey of Mexican Boundary, 1849, 1850, 1852, 1853, 1854, 1855.
Personal narrative.
A. D. Bache, Supt. Coast Survey, maps of Pacific coast and along Gulf of Mexico.
United States Land Office Surveys of Michigan, Indiana, Illinois, Wisconsin, Minnesota Issouri and Arkansas, up to spring of 1858.
Journey to Pembina, on Red river of Minnesota, 1857, by R Kennicott, of Illinois.
Nicollet's Report Expl. Upper Mississippi, 1843.
List of Plants by Dr. Torrey and C. Geyer.
Roemer's Texas, 1849.
A. Von Humboldt on Distribution of Plants, translated in Edin. Philos. Jour., vol. VI, VII, 1820.

Many other works have been consulted which were not made note of at the time, and also results given of personal explorations and observations made from Maine to Virginia, and across the continent through Nebraska, Oregon, Washington, and California.

CATALOGUE OF THE NATIVE TREES OF THE UNITED STATES.

A.—*Regions east of the Rocky Mountains.*

Number, &c.	Botanical name.	Popular name.	Height in feet.	Range to the NE.	Range to the SE.	Range to the NW.	Range to the SW.	Region of greatest abundance.
1	MAGNOLIA, *Linn.*	MAGNOLIA.						
a	glauca, *Linn*	Sweet Bay	25	Cape Ann, Mass	Florida	New York		CAR.
b	acuminata, *Linn*	Cucumber tree	80	Niagara, N. Y.	North Carolina		Tennessee	Ohio.
c	umbrella, *Linn.*, (*tripetala*, *Linn.*	Umbrella tree	40	Pennsylvania	Florida	Illinois	....do	Tenn.
d	fraseri, *Walter*, (*auriculata*, *Lamk*)	Ear-leaved	40	....do	Georgia		....do	Tenn.
e	var.? pyramidata, *Nutt*	Pyramid tree		South Carolina	Florida			Car.
f	macrophylla, *Mich*	Large-leaved	40	Lincolnton, N. C.	....do		Tennessee	Tenn.
g	cordata, *Michx*	Heart-leaved	50	South Carolina				Car.
h	grandiflora, *Linn*	Evergreen	70	Raleigh, N. C	Florida?	Natchez, Miss	Louisiana	Miss.
2	LIRIODENDRON, *Linn.*	TULIP TREE.						
	tulipifera, *Linn*	Whitewood, "*Poplar*"	140	Russell, Mass	Florida	Cape Girardeau, Mo.	Fort Smith, Ark	Tenn.
3	ASIMINA, *Adams.*	(*Anona*, *Parcelia.*)						
	triloba, *Linn*	Papaw	25	Niagara, N. Y	North Carolina	Mouth of Big Sioux river, Dac. T.	Texas	Tenn.
4	ZANTHOXYLUM, *Selden.*	Toothache tree, PRICKLY ASH.						
a	americanum, *Miller*	Northern		Massachusetts		Fort Pierre, Neb		Ohio.
b	carolinianum, *Lamk*	Southern		Sullivan's I	Florida		Texas	Car.
5	PTELEA, *Linn.*							
	trifoliata, *Linn*	Trefoil tree	20	New York	Florida	Council Bluffs, Iowa	Mimbres river, N. M.	Tenn.
6	RHUS, *Linn.*	SUMACH.						
a	typhina, *Linn*	*Staghorn*, *Velvet*	30	Quebec, C. E	Mountains, Ga	St. Croix, Wis	Texas	All.
b	glabra, *Linn*	*Smooth*	20	Canada East		Saskatchewan river	....do	All.
c	venenata, *D. C.*, (*vernix*, *Linn.*)	Poison Swamp	20	....do		......do	....do	Miss.
d	cotinoides, *Nutt.*, (*Cotinus americ.*, *Nutt.*)	Amer. Smoke tree	60		Huntsville, Ala	Grand river, Ark	....do.?	Tenn.
7	TILIA, *Linn.*	LINDEN, Lime, Basswood.						
a	americana, *Linn*	Northern	70	Canada East		Mouth of Saskatchewan river.		Car.
b	heterophylla, *Vent*	Southern	60?	Pennsylvania	Florida	Kentucky	Cross Timbers, Tex.	Miss.
8	GORDONIA, *Ellis.*							
a	lasianthus, *Linn*	Loblolly Bay	80	Norfolk, Va	Florida		Texas	Car.
b	pubescens, *L'Her*	Franklinia	50	Altamaha R., Ga				Miss.

9	VITIS, *Linn.*	GRAPEVINE.						
a	labrusca, *Linn*	Northern Fox	Vine.	Vermont	Mount's of Georgia.	Missouri		All.
b	vulpina, *Linn*, (*rotundifolia*, *Michx.*)	Southern Fox	Vine.	Maryland	Georgia	Kentucky		Car.
c	æstivalis, *Michx*	Summer Grape	Vine.	Vermont		Illinois	Texas	Ohio.
d	cordifolia, *Michx.*, (*riparia*, *Michx*)	Winter or Frost Grape	Vine.	....do	Mount's of Georgia.	Fort Laramie, Neb.		Ohio.
10	ACER, *Mœnch.*	MAPLE.						
a	saccharinum, *Wang*	Sugar	80	Lat. 48° C. E		Lake Winipeg	St. Croix riv., Wis.	Cda.
b	var.? nigrum, *Michx*	Black Sugar		Massachusetts?	Mount's of S. Car.		Mount's of Tenn.	All.
c	dasycarpum, *Ehrh.*, (*eriocarpum*, *Mich.*)	White or Soft	60	Sorel river, C. E.	Georgia	Wisconsin	Arkansas	Ohio.
d	rubrum, *Linn*, (*coccineum*, *Michx.*)*	Red or Swamp	80	Lat. 48°, C. E.	Florida?	Lake Winipeg	Louisiana	Cda.
e	pennsylvanicum, *Linn*, (*striatum*, *Lamk.*)	Striped; Moosewood	40	N. S.	Virginia	Wisconsin	Kentucky	Car.
11	NEGUNDO, *Mœnch.*	ASH-LEAVED MAPLE.						
a	aceroides, *Mœnch*	Box Elder	50	Pennsylvania	Wilcox Co., Ala.	Saskatchewan river	New Braunfels, Tex.	Ohio.
12	AESCULUS, *Linn.*	HORSE CHESTNUT.						
a	glabra, *Willd*, (*ohioensis*, *Michx.*)	Ohio Buckeye	60	Pittsburg, Pa.	Mount's of N. Car.	Big Sioux riv., Min.		Ohio.
b	macrostachya, *Michx*	Eatable Buckeye	15	South Carolina	Georgia	Cross Timbers, Tex.?		Tenn.?
c	pavia, *Linn.*		15	Pennsylvania?	...do	Arkansas	Louisiana	Miss.?
d	flava, *Aiton*, (*lutea*, *Michx.*)	Yellow Buckeye	80	Lat. 39°, Va.	Low country, Ga.	Illinois	Texas	Miss.
13	FRANGULA, *Tourn.*	BUCKTHORN.						
a	caroliniana, *Walter*	*Southern*	40	Coast of N. C.	Florida	Arkansas	Western Texas	Car.?
14	CLIFTONIA, *Sol.*							
	ligustrina, *Nutt*	Buckwheat-tree	20	Savannah, Ga.			Alabama	MISS.
15	ROBINIA, *Linn.*	LOCUST-TREE, *Acacia.*						
a	pseudacacia, *Linn*	*Common.*	90	Potomac river, Md.	Mount's of Georgia.	Michigan	Cross Timbers, Tex.	Tenn.
b	viscosa, *Vent*	*Sticky or clammy*	40	Mount's of Virginia.	......do	Missouri?		ALL.
16	CLADRASTIS, *Raf.*							
	tinctoria, *Raf.*, (*Virgilia lutea*, *Michx.*)	Yellow-wood	40	Kentucky.	Florida?	Arkansas		TENN.
17	CERCIS, *Linn.*							
a	canadensis, *Linn*	Red-bud, or *Judas-tree*	30	New Jersey	Mount's of Georgia.	Big Sioux riv., Iowa.	Cross Timbers, Tex.	Ohio.
18	GYMNOCLADUS, *Lamk.*	COFFEE-BEAN TREE.						
	canadensis, *Lamk*	Kentucky	80	Montreal, C. E.		Big Sioux riv., Iowa.	Cross Timbers, Tex.	Ohio.
19	GLEDITSCHIA, *Linn.*							
a	triacanthos, *Linn*	Honey Locust	80	Lat. 40° 42′, Pa.	Georgia	Big Sioux riv., Iowa.	Cross Timbers, Tex.	Tenn.
b	monosperma, *Walter*	Water Locust	50	Charleston, S. C.	Florida?		Swamps of Louisiana	Miss.
20	PRUNUS, *Tourn.*	PLUM.						
a	americana, *Marsh*	Wild, Yellow, or Red	20	Hudson's Bay?	Georgia	Saskatchewan river	Fort Washita, Tex.	Ohio.
b	chickasa, *Michx*	Chicasaw	10	Not native? in Ill.			Colorado river, Tex.	Tenn.?
21	CERASUS, *Jussieu.*	CHERRY.						
a	pennsylvanica, *Ser*	Wild Red	20	N. S.	Mount's of N. Car.		St. Croix, Wis.	Cda.

* The southern form varies much, and may be a distinct species. More specimens are wanted.

A.—*Regions east of the Rocky Mountains*—Continued.

Number, &c.	Botanical name.	Popular name.	Height in feet.	Range to the NE.	Range to the SE.	Range to the NW.	Range to the SW.	Region of greatest abundance.
21	CERASUS, *Jussieu.*	CHERRY.						
b	virginiana, *DC*	Choke	20	N. S.?	Columbia, S. C	Up. Missouri river, Neb.	Sandia mts., Tex	Ohio.
c	serotina, *DC.*, (*virginiana of Michx.*)	Wild Black	80	Labr.?	Uplands of Georgia.	Great Slave lake	Cross Timbers, Tex	Ohio.
d	caroliniana, *Michx.*	Southern Laurel, (*Wild Orange*).	50	Columbia, S. C	Florida	Lowlands of Ark	Lowlands of Texas.	Miss.
22	PYRUS, *Linn.*	PEAR AND APPLE.						
a	coronaria, *Linn.*	Sweet-scented Crab Apple.	20	New York	Georgia	St. Peter's, Wis		Ohio.
b	angustifolia, *Ait.*	Narrow-leaved Crab Apple	20	Pennsylvania	....do..			ALL.
c	americana, *DC.* (*Sorbus amer., Linn*)	Mountain Ash	30	N. S.	Mount's of Georgia.	Athabasca river	Cascade mts., Ore..	Ath.
23	CRATAEGUS, *Linn.*	HAWTHORN.						
a	crus-galli, *Linn.*	Cockspur	20	Canada East	Florida?	Indiana	Missouri?	All.
b	var.? prunifolia, *Poir*		20					
c	coccinea, *Linn.*	*White*	20	Canada East	Florida?	Wisconsin	Sandia mts., Texas.	Ohio.
d	var.? viridis, *Linn*							
e	tomentosa, *Linn.*	Downy-leaved	25	Canada East	Mountains of S. C.	Indiana	Kentucky	Ohio.
f	var.? punctata, *Jacq.*			....do	Mountains of Ga	Fort Union, Neb		Ohio.
g	arborescens, *Elliott*	Southern tree	30	Virginia	Florida		Texas	Miss.?
h	apiifolia, *Michx.*	*Parsley-leaved*	15	....do...	....do..		Louisiana	Car.?
i	aestivalis, *Torr. & Gray*	Summer-blooming	30	Low country of S. C.	....do..	Arkansas	....do	Miss.?
j	cordata, *Aiton*	*Heart-leaved*; Washington.	25	Washington, D. C..	Mountains of Ga	Kentucky		Tenn.
k	berberifolia, *Torr. & Gray*	Barberry-leaved	25	Opelousas, La ?				Miss.
l	flava, *Aiton*, (*glandulosa, Michx*)	Yellow-berried	20	Virginia	Florida			Car.
24	AMELANCHIER, *Medic.*	SERVICE-BERRY.						
a	canadensis, *Linn*	*Shad-blossom*	20	Labr	?	?		Cda.
b	var.? botryapium, *Linn*	*Southern*	15	New Jersey	Georgia	?		All.
c	var.? alnifolia, *Nutt*	*Western*	25	Lt.65°, Mackenzie R.	Copper mines, N. M	Russian America	Southern Oregon	Ath.
25	CORNUS, *Tourn.*	CORNEL, Dogwood.						
a	alternifolia, Linn.	Green Dogwood	20	C. E	Mountains of S. C..		Kentucky	All.
b	florida, Linn	Flowering Dogwood	30	Castleton, Vt.	Florida	Fort Leavenworth, K	Sabine river, La	Tenn.
26	LIQUIDAMBAR, *Linn.*	SWEET GUM.						
	styraciflua, *Linn*	Bilsted or Copalm	80	Connecticut R., Ct.	Florida	Southeastern Mo	Eastern Mexico	Miss.
27	NYSSA, *Linn.*	TUPELO, Sour gum.						
a	multiflora, *Wang*, (*aquatica*,) *Linn*	Pepperidge	60	Portsmouth, N. H..	Georgia	?Iron mountain, Mo.		Car.?

b	uniflora, *Walter*, (*grandidentata*, *Michx.*)	Southern	80	South Carolina	Florida	?Cross timbers, Tex.		Miss.
c	var. capitata, *Michx.*	Red berried	30	Ogeechee R., Ga.	....do....	Louisiana		Miss.
28	SAPINDUS, *Linn.*	SOAP-BERRY.						
	marginatus, *Willd.*	"Wild China"	40	Coast of S. C.	....do....	Source of Red river, Texas.	Sonora, western Mexico.	Miss.
29	CYRILLA, *Linn.*							
	racemiflora, *Linn.*	Carolina Ironwood	20	South Carolina	....do....			Car.
30	KALMIA, *Linn.*	MOUNTAIN LAUREL.						
	latifolia, *Linn*	*Spoonwood*, *Calico-bush*	20	York county, Me	Mountains of S. C.?	Perry county, Ark		All.
31	RHODODENDRON, *Linn.*							
[illegible]	maximum, *Linn.*	Great Laurel	25	Standish, Me.	Mountains of Ga.	Arkansas		All.
32	OXYDENDRON, *DC.*	SOUR-WOOD.						
	arboreum, DC., (*Andromeda*, *Linn*)	Sorel-tree	[illegible]	Pennsylvania	Florida	Ohio	Arkansas	Tenn.
33	ILEX, *Linn.*	HOLLY.						
	opaca, *Aiton*	American	40	York county, Me	....do....	Perry county, Ark.	Texas	Car.
34	DIOSPYROS, *Linn.*	EBONY.						
a	virginiana, Linn	Persimmon	20	Seacoast, R. I.	....do....	Kansas river, Kan.	Cross Timbers, Tex.	Miss.
35	CATALPA, *Scop.*	CATALPA.						
	bignonioides, *Walt.*	*Indian bean*	40	Columbus, Ga.	....do....	Union county, Ill.	Texas	Miss.
36	BUMELIA, *Swartz.*	BUMELIA.						
a	lycioides, *Gaertner*	Southern Buckthorn	25	Columbia, S. C		Kentucky.	....do....	Car.
b	lanuginosa, *Pers.*	Rusty Bumelia	50	South Carolina	Florida	Illinois	....do....	Miss.
c	tenax, *Willd.*	Silvery Bumelia	20	....do....	....do....			Car.
37	SYMPLOCOS, *Jacq.*							
a	tinctoria, *L'Herr*, (*Hopea*, *Linn*, *Michx.*)	Sweet-leaf, or V, Horse sugar	30	Petersburg, Va.		Tennessee	Louisiana	Tenn.
38	HALESEA, *Ellis.*							
a	tetraptera, *Linn.*	Silver-bell tree	50	Washington, D. C.		Evansville, Ky.		Tenn.
b	diptera, *Linn*	Or *Snowdrop tree*	15	Savannah, Ga.				Miss.?
39	PINCKNEYA, *Michx.*							
	pubens, *Michx.*	Georgia bark	30	Cult. at Charleston, S. C.	Florida			Miss.
40	OLEA, *Tourn.*	OLIVE.						
	americana, *Linn*	Devil-wood	20	Norfolk, Va.	Florida		Texas	Miss.
41	CHIONANTHUS, *Linn.*							
	virginica, *Linn.*	Fringe-tree	70	Pennsylvania	Florida			CAR.
42	FRAXINUS, *Tourn.*	ASH.						
a	americana, *Linn.*, (*epiptera*, *Michx.*)	White	80	New Braunfels	Georgia	Saskatchewan river	Cross Timbers, Tex.?	Cda.
b	pubescens, *Lamk.*, (*tomentosa*, *Michx.*)	Red	60	Burlington, Vt.	Georgia			ALL.
c	viridis, *Michx.*, (*juglandifolia*, *DC.*)	Green	40	Maine			Eagle Pass, Texas.	Tenn.?
d	sambucifolia, *Lamk.*	Black or Water	70	New Braunfels	Pennsylvania	Saskatchewan river	Missouri	Cda.

A.—*Regions east of the Rocky Mountains*—Continued.

Number, &c.	Botanical name.	Popular name.	Height in feet.	Range to the NW.	Range to the SE.	Range to the NW.	Range to the SW.	Region of greatest abundance.
42	FRAXINUS, *Tourn.*	ASH.						
e	quadrangulata, *Michx*	Blue	70	Michigan	Ohio	Missouri	Tennessee	OHIO.
f	platycarpa, *Michx*	Carolina	30	Virginia	Georgia		Mississippi	Car.
43	PERSEA, *Gaertner.* carolinensis, *Nees.*, (*Laurus carol. Michx.*)	Alligator Pear or Red Bay	70	Lat. 38° 30′, Del.	Florida		Louisiana	CAR.
44	SASSAFRAS, *Nees.* officinalis, *Nees*	Sassafras	50	Portsmouth, N. H.	Mountains of Ga.	Kansas river, Kan.	Verdigris river, Tex.	Tenn.
45	ULMUS, *Linn.*	ELM.						
a	fulva, *Michx.*, (*rubra, Michx., f.*)	Slippery or Red	60	Natick, Mass.	Georgia	Fort Pierre, Neb.	New Braunfels, Tex.	Ohio.
b	americana, *Linn*	White or Drooping	80	Misstassin river, C.E	Mountains of Ga.	Saskatchewan river	New Braunfels, Tex.	Cda.
c	racemosa, *Thomas*	Northern Corky	50	Lake Champlain, Vt.		Saskatchewan riv'r?		OHIO.
d	alata, *Michx.*, (*pumila, Walt.*)	Wha-hoo or Southern Corky	50	Low country, Va.	Georgia	Iron Mountain, Mo.	Eagle Pass, Tex.	Miss.
e	crassifolia, *Nutt.*, (*var. opaca, Nutt.*)	Thick-leaved	50?	Arkansas?	San Antonio, Texas	Arkansas river, Ark.	Pecos river, Texas.	MISS.
46	PLANERA, *Gmel.* aquatica, *Gmel.*, (*ulmifolia, Michx.*)	Planer tree	40	Wheeling, Va.	Georgia	Kentucky		Miss.?
47	CELTIS, *Tourn.*	NETTLE-TREE.						
a	occidentalis, *Linn*	Hack berry, Sugar-berry	70	Vermont		Council Bluffs, Iowa	Cross Timbers, Tex.	Tenn.?
b	mississippiensis, *Bosc*	Hoop ash, Southern Hack-berry	80	Illinois	Georgia?		Louisiana	MISS.
c	var? integrifolia, *Nutt*			Arkansas river, Ark.				MISS.
48	MACLURA, *Nutt.* aurantiaca, *Nutt*	FUSTIC-WOOD. Osage Orange	30	Jasper county, Mo.	Nachitoches, La.	Texas	Mexico?	TENN.
49	MORUS, *Tourn.*	MULBERRY.						
a	rubra, *Linn*	American Red	70	Pownal, Vt.	Georgia	Fort Pierre, Neb.	Devil's river, Texas	Ohio.
50	PLATANUS, *Linn.*	SYCAMORE.						
a	occidentalis, *Linn*	Button-wood, *Water-beech, Plane-tree.*	80	Portland, Me.	Georgia	Lat. 24° 24′, Missouri river.	Santa Rosa, Mexico	Ohio.
51	JUGLANS, *Linn.*	WALNUT.						
a	cinerea, *Linn.*, (*cathartica, Michx.*)	Butter or Oil-nut	60	Maine	Mountains of Ga.	Big Sioux river, Iowa	Franklin co., Mo.	All.
b	nigra, *Linn*	Black	80	Intr.? into Mass.	North Carolina	Big Sioux river, Iowa	Cross Timbers, Tex.	Ohio.

52	CARYA, *Nutt.*	HICKORY.						
a	olivæformis, *Nutt.*	Pecan-nut	60 ?	Louisville, Ky.		Iowa	San Pedro riv., Tex.	Miss.
b	alba, *Nutt.*, (*squamosa, Michx.*)	Shell-bark	[illegible]	Portsmouth, N. H.	Mountains of Ga.	Missouri	Louisiana ?	All.
c	sulcata, *Nutt.*, (*laciniosa, Michx.*)	Thick Shell-bark	80	Springfield, Pa.	Georgia	Missouri		Tenn.
d	tomentosa, *Nutt.*	Mocker-nut	75	Portsmouth, N. H.	Georgia	Missouri	Louisiana ?	Ohio.
e	microcarpa, *Nutt.*, (*aquatica, Michx.*)	Water	50	Pennsylvania	Georgia	Missouri ?	Louisiana	Miss. ?
f	glabra, *Torrey*, (*porcina, Nutt.*)	Pig-nut or Broom	80	Portsmouth, N. H.	Mountains of Ga.	Franklin co., Mo.	Washita river, Ark.	Tenn.
g	amara, *Nutt.*	Bitter or Swamp	40	Burlington, Vt.	Georgia	Missouri	New Braunfels, Tex.	Tenn.
h	var? myristicæformis, *Michx*	Nutmeg	?	Charleston, S. C.			Opelousas, La.	Miss. ?
		§1. *White oaks; leaves lobed but not prickly or sharp pointed.*						
53	QUERCUS, *Linn.*	OAK.						
a	macrocarpa, *Michx.*, (*and olivæformis, Mx.*)	Bur; Overcup	70	Dover, N. Y	Virginia	Fort Benton, Neb.	San Saba river, Tex.	Ohio ?
b	alba, *Linn*	White	100	Lat. 46° 20′ C. E.	Cape Canaveral, Fla	Wisconsin	Cross Timbers, Tex	All.
c	obtusiloba, *Michx.*, (*stellata, Willd*)	Post, Box, or Iron	50	Martha's Vineyard, R. I.	Florida	Saskatchewan river	Cross Timbers, Tex	Tenn ?
d	lyrata, *Michx*	Southern overcup, Swamp-post, or White.	80	North Carolina	St. John's R., Fla.		Louisiana	Miss ?
		§ 2. *Chestnut oaks; leaves toothed but not lobed; acorns sweet tasting.*						
e	prinos, *Willd.*, (*palustris, Michx*)	Swamp Chestnut	40	Philadelphia, Pa.	Eastern Florida	Missouri	Louisiana	Miss ?
f	var? discolor, *Michx.*, (*bicolor, Willd*)	Swamp White	40	Portsmouth, N. H.	Georgia	Wisconsin	Knoxville, Tenn.	Ohio ?
g	castanea, *Willd.*, (*acuminata, Michx*)	Yellow Chestnut	80	Saco, Me.	Highlands, Ga	Missouri	Potter county, Ark.	Tenn.
h	var? monticola, *Michx.*, (*montana, Linn*)	Rock Chestnut	60	New Hampshire		Blacksnake hill, Min	Kimishi mts., Tex.	Tenn.
		§ 3. *Live oaks and willow oaks; leaves entire, evergreen and persistent.*						
i	virens, *Aiton*	Live	40	Norfolk, Va.	Florida	Live Oak creek, Tex	Mexico ?	Car ?
j	imbricaria, *Michx*	Laurel; Blackjack	50	New Jersey	Mountains, Ga		Head of Arkansas river, K.	Tenn.
k	phellos, *Linn*	Willow	60	Long Island, N. Y.	Georgia		Arkansas ?	CAR.
l	cinerea, *Michx*	Upland Willow	20	South Carolina			New Braunfels, Tex	MISS.
		§ 4. *Thick leaved oaks; leaves smooth, entire, and bristle pointed.*						
m	aquatica, *Catesby*	Water	45	Richmond, Va.	Florida		Arkansas	Miss.
n	nigra, *Linn.*, (*ferruginea, Michx*)	Blackjack, Barren	30	Allentown, N. J.	North Carolina	Illinois	San Antonio, Tex.	Tenn.
o	var? heterophylla, *Michx*	Bartram's	30	Philadelphia, Pa.	(*hyb. of n. and k ?*).	Missouri ?		
p	var? leana, *Nutt*	Lea's		Augusta, Ill.	Cincinnati, Ohio.	(*hyb. of n. and j. or r.*)		
		§ 5. *Black and Red oaks; leaves deeply lobed, bristle pointed.*						
q	falcata, *Michx*	Spanish; *Red*	80	Allentown, N. J.	——, Ga.	——, Mo	——, Ark.	Car ?
r	tinctoria, *Bartram*	Black; *Dyeing*	90	York county, Me.	—— mts., Ga.	Big Sioux river, Iowa	——, Ark.	All ?
s	coccinea, *Wang*	Scarlet	80	Boston, Mass.	—— mts., Ga.	——, Mo	New Braunfels, Tex	Tenn ?
t	rubra, *Linn*	Red	80	——, C. E.	——, Ga.	Big Sioux river, Iowa	New Braunfels, Tex	Tenn ?
u	var? borealis, *Michx*	Gray; *Northern*	60	Quebec, C. E.	——, Mass.	Saskatchewan river	——, Mo.	Cda.
v	palustris, *Du Roi*	Pin; Swamp	80	Massachusetts	Mountains, Ga.	Missouri	Fort Chadbourne, Tex.	Tenn.

A.—*Regions east of the Rocky mountains*—Continued.

Number, &c.	Botanical name.	Popular name.	Height in feet.	Range to the NE.	Range to the SE.	Range to the NW.	Range to the SW.	Region of greatest abundance.
54	CASTANEA, *Tourn.*	CHESTNUT.						
a	americana, *Linn*	American	80	York county, Me	Mountains of Georgia.	Missouri	Hills of Northern Mississippi.	Tenn?
b	pumila, *Michx*	Chinquapin	40	Pennsylvania	Florida	Perry county, Ark.	Cross Timbers, Tex	Miss.
55	FAGUS, *Tourn.*	BEECH.						
a	ferruginea, *Aiton*	Red, Northern.	90	New Brunswick	Rhode Island	Lake Winipeg	Wisconsin	Cda.
b	var? sylvestris, *Michx*	White, Southern.	120	New Jersey	Mountains of Georgia.	Missouri	Texas	Tenn.
56	CARPINUS, *Linn.* americana, *Michx*	HORNBEAM. Iron wood, Blue Beech	30	New Brunswick	Georgia	St. Croix, Wis	Missouri	Cda.
57	OSTRYA, *Micheli.* virginica, *Willd*	HOP-HORNBEAM. Lever wood	40	New Brunswick	Georgia	Lake Winipeg	Kimishi mts., Ark.	Cda.
58	BETULA, *Tourn.*	BIRCH.						
a	populifolia, *Aiton*	White; *Oldfield*	40	New Brunswick	Mountains of Virginia.	....	? Black Hills, Neb.	All.
b	papyracea, *Aiton*, (*papyrifera*, *A. Michx.*)	Paper; *Canoe*	60	Labr	Mountains of Virginia.	Lat. 69°, Mackenzie's river.	? Lat 48°, W. T.	Athab.
c	nigra, *Linn.*, (*rubra*, *Michx*)	Red; River	70	Northern Massachusetts.	Mountains of Georgia.	Missouri	Tennessee?	All.
d	excelsa, *Aiton*, (*lutea*, *Michx*)	Yellow	70	New Brunswick	Mountains of Pennsylvania.	East end of Lake Superior.	Wisconsin?	CDA.
e	lenta, *Linn.*, (*carpinifolia*, *A. Michx*)	Sweet; Cherry; Black	80	Nova Scotia	Mountains of Georgia.	....	....	ALL.
59	ALNUS, *Tourn.*	ALDER.						
a	incana, *Willd.*, (*glauca*, *Michx*)	Speckled	20	New Hampshire	Massachusetts	Lat. 68°, Mackenzie's river.	Wisconsin	Ath?
b	viridis, D. C., (*crispa*, *Michx*)	Green; Mountain	20	Labr?	Mountains of New Hampshire.	? Kotzebue's sound.	? Cascade mts., O. T.	Ath.
60	SALIX, *Tourn.*	WILLOW.						
a	nigra, *Marshall*, (*ligustrina*, *Michx*)	Black; *Southern*	35	Vermont	Georgia	....	....	Tenn?
b	lucida, *Michx*	Shining; *Northern*	20	Vermont	....	Lat. 67°, Mackenzie's river.	? Colorado river, Ariz.	Athab.
c	subvillosa, *Elliot*, (*longipes*, *Shuttleworth.*)	*Downy leaved*	20	North Carolina?	Florida	....	....	CAR.

61	Populus, *Tourn.*	Poplar.						
a	tremuloides, *Michx*	American Aspen	50	New Brunswick	Westchester, Penn.	Lat. 64°, Russian Am.	San Francisco mts., N. M.	Ath.
b	grandidentata, *Michx*	Soft Aspen	40	......do.	? Mountains of Ga.	....	Iowa	Algon.
c	heterophylla, *Linn.*, (*argentea, Michx*)	Downy-leaved	60	Maine	Georgia	Illinois	Louisiana	Car. ?
d	monilifera, *Aiton*	Northern Cottonwood, "*Virginian*" *Swiss.*	70	....	....	Lat. 49°, W. Ter.	Fort Yuma, N. M.	West'n
e	var.? canadensis, *Michx*	Canadian	80	Hoosic river, Vt.	Virginia	? Nebraska	? Arkansaw river	Ohio.
f	angulata, *Aiton*	Southern Cottonwood	80	Conn. river, Mass.	Georgia	Booneville ? Mo.	Cross Timbers, Tex.	Miss.
g	balsamifera, *Linn.*	Balsam Poplar, *Tacamahac*	80	Newfoundland	New Hampshire	? Lat. 69°, Russ. Am.	Wisconsin	Athab.
h	var.? candicans, *Michx*	Balm of Gilead	50	N. S.	New Jersey	Lat. 49°, Minn.	Kentucky	All ?
[illegible]	Pinus, *Tourn.*	Pine.						
	§ 1. Leaves in 2's.							
a	banksiana, *Lamb.*, (*rupestris, Michx*)	Gray; *Scrub*	20	C. E. ?	Black Hills, Neb.	Lat. 64°, Brit. Am.	? Spokan riv., W. T.	Athab.
b	inops, *Aiton*	Jersey; *Scrub*	40	New Jersey	Georgia	Mudlick, Ky.	....	All.
c	pungens, *Michx*	Table Mountain	50	Lat. 38°, Blue Ridge, Va.	Stone mountain, Ga	Tennessee ?	Alabama ?	All.
d	resinosa, *Aiton*, (*rubra, Michx*)	Red; "*Norway*"	80	Lat. 48°, C. E.	Lat. 41° 30, Penn.	Lat. 56° 30', Brit. Am.	St. Croix, Wis.	Cda.
e	mitis, *Michx.*, (*variabilis, Pursh*)	Yellow; *Spruce*	60	Massachusetts ?	Florida	? Nebraska	Kimishi mts., Ark.	Tenn. ?
	§ 2. Leaves in 3's.							
f	rigida, *Miller*	Northern Pitch	70	Penobscot river, Me.	Mountains of Ga.	Black Hills, Neb.	Kimishi mts., Ark.	All ?
g	var.? serotina, *Michx*	Pond Pine	40	South Carolina	....	....	....	Car.
h	taeda, *Linn*	Loblolly; Oldfield; *White*	100	Cecil county, Md.	Florida	Arkansas	Austin, Texas	Miss.
i	palustris, *Linn.*, (*australis, Michx*)	Southern Pitch; Long-leaved; *Broom*	100	Norfolk, Va	Florida	Louisiana ?	Louisiana ?	Car.
	§ 3. Leaves in 3's.							
j	strobus, *Linn*	Northern White	100	Lat. 48° 50', C. E.	Mountains of Ga.	Lake Winipeg.	St. Croix Falls, Wis.	Cda.
63	Abies, *Tourn.*	Spruce; Fir.						
a	balsamea, *Marsh*	American Balsam	40	Labr.?	Mountains of Penn.	Lat. 62°, Mack. riv., Br. Am.	Manitowoc, Wis.	Athab.
b	fraseri, *Pursh.*, (*balsamifera, Michx. Pl. C. L.*)	Southern Balsam	45	Mountains of Penn.	Stone mountain, Ga.	....	....	All
c	canadensis, *Michx*	Hemlock	80	Hudson's Bay, Bect.	Mountains of Ga.	? Sitka river, Am.	Wisconsin	Cda.
d	nigra, *Poir*, (*rubra, Lambert*)	Black; *Double*	80	Labr.?	......do.	Lat. 68°, Mack. riv.	Black Hills, Neb.	Athab.
e	alba, *Michx*	White; Single	50	Labr.	Mountains of Va.	Lat. 67°, Mack. riv.	? Rocky mts., lat. 38°	Algon ?
64	Larix, *Tourn.*	Larch.						
a	americana, *Michx.*, (*microcarpa, Lamb., pendulus, Aiton.*)	Tamarack; Hackmatac	100	Lat. 63°, Labr.	Mountains of Va.	Lat. 67° 30', Mack. river.	St. Croix, Wis.	Athab.
65	Thuja, *Tourn.*	Arbor vitae.						
a	occidentalis, *Linn*	Northern White Cedar	50	Labr.	Mountains of Va.	Lat. 54°, Sark. riv.	St. Croix, Wis.	Algon?
66	Cupressus, *Tourn.*	Cypress.						
a	thyoides, *Linn*	Southern White Cedar, "*Juniper*"	80	Mass.	Augusta, Ga.	Ohio ?	....	Car.
67	Taxodium, *Rich.*	Bald Cypress.						
	distichum, *Rich.*	American	120	Lat. 38° 30', Del.	Florida	Illinois	Salado river, Mex.	Miss.
68	Juniperus, *Linn.*	Juniper.						
a	virginiana, *Linn*	Red Cedar, or Juniper	50	Kennebec river, Me.	Florida	? Lat. 67°, Mack. riv.	Roubideau's Pass, Texas.	All?

A.—*Regions east of the Rocky mountains*—Continued.

Number, &c.	Botanical name.	Popular name.	Height in feet.	Range to the NE.	Range to the SE.	Range to the NW.	Range to the SW.	Region of greatest abundance.
68	JUNIPERUS, *Linn.*	JUNIPER.						
b	communis, *Linn.*	Northern	15	Labr.	Massachusetts	Lat. 67°, Mack. riv.	Cascade mountains, O. T.	Athab.
69	TAXUS, *Tourn.*	YEW.						
a	canadensis, *Willd.*, (*baccata*, *var.*? *Linn.*)	Ground Hemlock	?20	Newfoundland	Mountains of Va.	Lat. 54°, Sask. riv.	Chicago, Ill.	Algon?
70	TORREYA, *Arnott.*	TORREYA.						
a	taxifolia, *Arr*	Yew-leaved; Florida	40	Florida				FLA.
71	CHAMAEROPS, *Linn.*	GROUND-PALM.						
	palmetto, *Linn*	Palmetto	90	Cape Hatteras, N.C.	Cape Sable, Fla.	San Antonio, Texas	? Mexico	Fla.
72	ARUNDINARIA, *Michx.*	CANE.						
	macrosperma, *Michx*	Giant	35	Washington, D. C.	Florida	? Lat. 38°, Kansas	Texas	Miss.

B.—*Regions of the Rocky mountains and westward to the Pacific.*

Number, &c.	Botanical name.	Popular name.	Height in feet.	Range to the NE.	Range to the SE.	Range to the NW.	Range to the SW.	Region of greatest abundance.
6	RHUS, *Linn.*	SUMACH.						
f	microphylla, *Englm.*	Small-leaved	15	Eagle Pass, Tex.		Colorado river, N.M.		Ariz.
74	PHOTINIA, *Lindl.*							
	arbutifolia, *Lindl.*		20			Monterey, Cal.	San Diego, Cal.	Cal.
9	VITIS, *Linn.*	GRAPEVINE.						
e	californica, *Benth*	Californian		Fort Reading, Cal.	Sonora, Mex.		San Diego, Cal.	Cal.
f	rupestris, *Scheele*	Arizonian		Texas		Yampai creek, N.M.		Ariz.
10	ACER, *Moench.*	MAPLE.						
f	macrophyllum. *Pursh*	Large-leaved; white	90		Lat. 43°, Mts. of Cal.	Russian America	Santa Barbara, Cal.	Oreg.
g	circinatum, *Pursh*	Round-leaved; vine	40		Mountains of California.	Russian America		Oreg.
h	glabrum, *Torrey*	Smooth-leaved	30?		James' Peak, R. mts.		Straits of Fuca, W. T.	Koot.
i	tripartitum, *Nutt*	Trifid-leaved	20?		Bear river, Utah		Cascade Mts., O. T.	Was?
j	grandidentatum, *Nutt*	Notch-leaved	20?		Lat. 50°, Brit. Col.			Yukon?
11	NEGUNDO, *Moench.*	ASH LEAVED MAPLE.						
b	californicum, *Hkr*	Californian Box elder	30	Bear river, Utah	New Braunfels, Tex.		California	Cal.

12	AESCULUS, *Linn.*	HORSE CHESTNUT.						
e	californica, *Nutt.*	Cal'a Buckeye	40	Lat. 40°, Cal.	California			CAL.
13	FRANGULA, *Tourn.*	BUCKTHORN.						
b	purshiana, *De C.*	Bear wood; *Oregon*	30		Salmon river, O. T	Nootka Sound, V. I.		OREG.
c	californica, *Gray*	Californian	15	Lat. 42°, Cal.	Camp Bache, Tex.		Lat. 32°, Cal.	Cal.
126	CEREUS, *Haw.*	RIBBED CACTUS.						
a	giganteus, *Englm.*	Saguaro	50	Williams' river, lat. 34°.			Sonora, Mex.	ARIZ.
b	thurberi, *Englm.*	Pitahaya	30	Gila river			Sonora, Mex.	Ariz?
128	OPUNTIA, *Tourn.*	PRICKLY PEAR.						
a	arborescens, *Englm*	Tree formed	12	Llano Estac., Tex.		Zuñi, N. M.		ARIZ.
b	bigelovii, *Englm.*	Bigelow's	12	Williams' river, N. M.			Lower California?	Ariz.
c	acanthocarpa, *B. & E.*	Spring fruit	6	Cactus Pass, N. M.				ARIZ.
d	fulgida	Brilliant; choya		Gila river to Sonora.				Ariz?
76	ALGAROBIA, *D C.*	Mesquite tree.						
	glandulosa, *Torr.*	Honey-pod		Long. 96°, on Red river, Tex.	Mexico	Coast mts., N. M.		Ariz.
77	STROMBOCARPA, *Torr.*	Mesquite tree.						
	pubescens, *Gray*	Screw-pod		Doña Ana, N. M.	do	Vegas, Utah		ARIZ.
17	CERCIS, *Linn.*	REDBUD.						
b	occidentalis, *Torr.*	Californian		Ft. Chadbourne, Tex	Saltillo, Mex.	Sacramento riv., Cal		Cal.?
79	BERBERIS, *Linn.*	BARBERRY.						
a	fremontii, *Torr*	Arizonian	15	Pecos river, Tex.		Rio Virgen, N. M		Ariz.?
80	CEANOTHUS, *Linn.*	CEANOTHUS.						
	thyrsiflorus, *Esch.*	"Wild Lilac"	20			San Francisco, Cal.	San Diego, Cal.	CAL.?
23	CRATAEGUS, *Linn.*	HAWTHORN.						
m	sanguinea, *Pall?*	Siberian			? South Pass, O. T.			Yukon?
n	rivularis, *Nutt*	Oregon		? Lat. 50°, R. mts			Willamette riv., O. T.	Koot.?
21	CERASUS, *Jussian.*	CHERRY.						
e	mollis, *Dougl.*	Oregon	30		Pit river, Cal.	Russ. Am.		OREG.
f	ilicifolia, *Nutt.*	Holly-leaved			Williams' riv., N. M.	Santa Barbara, Cal.	Lat. 32°, California.	Ariz.?
g	demissa, *Nutt.*	Shrubby	20		Sonora, Cal.	Steilacoom, W. T.	San Diego, Cal.	Cal.
20	PRUNUS, *Tourn.*	PLUM.						
c	subcordata, *Benth.*	Calif	6	Klamath lake, O. T	Yuba river, Cal.		San Felipe, Cal.	Cal.?
22	PYRUS, *Linn.*	PEAR OR APPLE.						
d	rivularis, *Dougl.*	Oregon crab	40		Santa Rosa cr'k, Cal.	Lat. 57°, Russ. Am.		Oreg.
25	CORNUS, *Tourn.*	CORNEL.						
c	pubescens, *Nutt*	Green	20		Duffield's ranch, Cal.	Steilacoom, W. T.	San Diego, Cal.	Cal.
d	nuttallii, *Aud.*	Oregon dogwood	60		do	do	Sitcha? Russ. Am.	Monterey, Cal.	Oreg.?
e	sessilis, *Torr.*	California	15	Grass Valley, Cal.				Cal.

B.—*Regions of the Rocky mountains and westward to the Pacific*—Continued.

Number, &c.	Botanical name.	Popular name.	Height in feet.	Range to the NE.	Range to the SE.	Range to the NW.	Range to the SW.	Region of greatest abundance.
31	RHODODENDRON, *Linn.*	Great Laurel.						
b	? maximum, *Linn*	Northwestern	30	.....	.....	Straits of Fuca, W. T.	Coast mts., O. T...	OREG.
83	ARBUTUS, *Tourn.*	Strawberry tree.						
	menziesii, *Pursh*	Madroña; laurel	50	.....	Coahuila, Mex.....	....do........do....	.....	Cal.
84	ARCTOSTAPHYLOS.	BEARBERRY.						
a	glauca, *Lindl*	Manzanita	20	Oregon Territory...	California.........	.....	.....	Cal.
b	tomentosa, *Dougl.*	Manzanita	20	Vancouver, W. T..	.....	.....	San Diego mts., Cal.	Cal.
36	BUMELIA, *Swartz.*	BUMELIA.						
f	? reclinata, *Vent.*	Loma; spreading	30	? South Carolina....	Mouth of the Rio Grande, Tex.	.....	Sonora, Mex.......	Ariz.?
42	FRAXINUS, *Tourn.*	ASH.						
g	pistaciaefolia, *Torr.*, (*velutina, Torr.*)..	Arizonian	30	Rio Grande, N. M..	Mexico.............	Williams' riv., N. M.	Sonora, Mex.......	ARIZ.
h	oregona, *Nutt.*	Oregon	60	.....	.....	Straits of Fuca, W. T.	Napa, Cal.........	OREG.
82	OREODAPHNE, *Nees.*	MOUNTAIN BAY.						
	californica, *Nutt.*, (*umbellularia, Nutt; Drimophylum pauciflorum, Nutt.*)	"Laurel"	70	Lat. 42°, California.	.....	.....	Lat. 32°, California.	CAL.
47	CELTIS, *Tourn.*							
d	reticulata, *Torr*	Rough-leaved Hackberry	30	Pike's Peak, R. Mts.	Pecos river, Texas.	Fort Dalles, O. T...	Lat. 32°, Arizonia..	Ariz.?
50	PLATANUS, *Linn.*	SYCAMORE.						
b	racemosa, *Nutt.*, (*mexicana, Moric.*)...	Mexican	80	.....	Rio Mimbres, N. M.	Lat. 42°, California.	Mexico............	Cal.
51	JUGLANS, *Linn.*	WALNUT.						
c	rupestris, *Engelm*	Arizonian	60	.....	Rio Grande, N. M..	Los Angelos, Cal...	....do.............	ARIZ.?
53	QUERCUS, *Linn.*	OAK.						
	§ 1. *White Oaks.—Leaves lobed and toothed, but not prickly.*							
*a**	douglassii, *Hkr*	*Douglass' White*	80	.....	California	.....	California.........	CAL.
b	gambelii, *Torr*	New Mexican White	60	Santa Fé, N. M....	.....	San Francisco mts., N. M.	New Mexico.......	ARIZ.?
c	garryana, *Dougl.*	Oregon White	70	Yakima riv., W. T.	California	Vancouver's Island.	California?.........	Oreg.
	§ 2. *Live Oaks.—Leaves entire or toothed; evergreen or persistent.*							
d	densiflora, *Hkr.*, (*echinacea, Torr.*).....	Evergreen Chestnut	40	Sacramento riv., Cal.	.....	Downieville, Cal...	San Diego mts., Cal.	CAL.

e	chrysolepis, *Liebm.*, (*fulvescens, Kellogg; crassipocula, Torr.*)	Thick cup	50	Canoe creek, Cal.	Tejon Pass, Cal.			CAL.
f	var? oxyadenia, *Torr.*	Sharpacoun		Yampah creek, N.M.		Santa Isabel, Cal.		Ariz.
n	confertifolia, *H. B. K.*	Vellote?		Mimbres, N. M.		San Francisco mts., N. M.	Sonora, Mex	ARIZ.?
g	lobata, *Nees*	Lobe-leaved Live					Monterey, Cal.	CAL.?
h	hindsii, *Bentham*, (*longiglanda, Torr.*)	Long-acorned	80	Sacramento riv., Cal	Fort Tejon, Cal.			Cal.
i	agrifolia, *Nees*	Holly-leaved	50	Fort Reading, Cal.			San Diego mts., Cal.	Cal.
j	emoryi. *Torr.*	Upland Live	50	Lat. 35°, N. M.	Rio Grande, N. M.	Yampah creek, N.M.	Sonora, Mex.	ARIZ.
k	oblongifolia, *Torr.*	Oblong-leaved	30	Limpia mts., N. M.			San Diego mts., Cal.	Ariz.
	§ 3. *Red and Black Oaks.—Leaves lobed and toothed, with bristly joints; deciduous.*							
l	californica, *Torr.*, (*kelloggii, Newb.*)	California Black	60	Lat. 42°, California.	California	Coast mts., Cal	do ... do	CAL.
54	CASTANEA, *Tourn.*	CHESTNUT.						
e	chryophylla, *Dougl.*, (*sempervirens, Kell.*)	Evergreen	70	Mount Hood, O. T.	do	Oregon Territory	Monterey, Cal.	Oreg.?
58	BETULA, *Tourn.*	BIRCH.						
f	glandulosa, *Michx.*	Bitter	20				Mts., lat. 44°, O. T.	Koot.?
g	occidentalis, *Hkr.*	Northwestern					Des Chutes river, O. T.	Koot.?
59	ALNUS, *Tourn.*	ALDER.						
c	oregona, *Nutt.*	Oregon. (See also *A. viridis.*)	60		Boisèe river, O. T.	Straits of Fuca, W. T.	San Diego? Cal.	OREG.
60	SALIX, *Tourn.*	WILLOW.						
d	wrightii, *Anders.*	Mexican	25	Rio Grande, Tex.			Chihuahua, Mexico	Chih.?
e	fendleriana, *Anders.*, (*speciosa, Nutt.*)	Beautiful	20		Fort Boisèe, O. T.		Columbia riv., O. T	Shosh.?
f	pentandra, *Willd.*, (*caudata, Nutt.*)	Bay-leaved	15		Rocky mts., lat. 42°.		Willamette riv., O. T.	Shosh.?
g	hookeriana, *Barrett.*	Oregon	40		Willamette riv., O.T.	Coast of O. T.		Oreg.
h	longifolia, *Michl.*	Long-leaved	40	Nebraska	Pecos river, Tex.	? Lat. 68°	Colorado river, N. M.	Yukon?
i	brachystachys, *Benth.*, (*scouleriana, Barr.*)	Coast	40			Coast of O. T	Monterey, Cal.	Oreg.
j	lasiolepis, *Benth.*	Woolly scaled	25	California				CAL.
61	POPULUS, *Tourn.*	POPLAR; Cottonwood.						
i	angustifolia, *Tourn.* (*See also P. monilifera and tremuloides.*)	Narrow-leaved	80	British America	Santa Fé, N. M.	Russian America	Colorado river, N.M.	Koot.?
62	PINUS, *Tourn.*	PINE.						
	§ 1. Leaves in pairs, (or single.)							
k	monophyllus, *Torr.*	One-leaved nut	60	Raton Pass, N. M.		Carson's Pass, Cal.	Mohave river, Cal.	Utah?
l	edulis, *Engelm.*	New Mexican nut	80	Cimarron riv., N. M.	Limpia mts., Tex.	Cajon Pass, N. M.	Sonora, Mexico	Ariz.
m	contorta, *Dougl.*, (*inops*,) *Hkr.*	Twisted; *scrub*	60		Sonora Cal.	Straits of Fuca, W. T.		Oreg.
	§ 2. Leaves in 3's or 4's.							
w	muricata, *Don.*		20			Monterey, Cal		CAL.?
n	sabiniana, *Dougl.*	Californian nut	150	Fort Lane, O. T.	Laguna river, Cal.		San Diego mts., Cal	CAL.?
o	var.? coulteri, *Don.*					Lat. 36°, Cal.		CAL.?
p	ponderosa, *Dougl.*, (*brachyptera, Engelm.*,) (*engelmanni, Torr.*)	Heavy yellow	100		Zuñi mts., N. M.	Fort Steilacoom, W. T.	Cactus Pass, N. M.	Shosh.
q	insignis, *Dougl.*	Western pitch	40	Lat. 43°, O. T.	Mount Diabolo, Cal.	Yuba river, Cal.	Monterey, Cal.	CAL.

* Western group.

B.—*Regions of the Rocky mountains and westward to the Pacific*—Continued.

Number, &c.	Botanical name.	Popular name.	Height in feet.	Range to the N. E.	Range to the S. E.	Range to the N. W.	Range to the SW.	Region of greatest abundance.
	§ 3. Leaves in 5's.							
r	flexilis, *Torr.*	Flexible; mountain	30	......	Sandia mts., N. M.	Pike's Peak, R. mts.	......	PAD.
s	llaveana, *Scheid.*, (*cembroides*, *Newb.*)	Newberry's	50	Cascade mts., O. T.	......	......	San Diego mts., Cal.	CAL.?
t	monticola, *Dougl.*, (*strobus. Hkr.*)	Rocky mountain white	50	Rocky mts., lat. 52°?	......	......	? Cascade mts., W.T.	Yukon?
u	lambertiana, *Dougl.*, (*strobiformis? Engelm.*)	Sugar	300	Lat. 43°, O. T.	? Raton Pass, N. M.	......	San Diego mts, Cal.	Cal.
v	wislizeni, N. S., (*flexilis*, *Engelm.*, not Torrey,) in Wislizenus' tour.—Sen. Doc. No. 26, 1848, p. 89; from Santa Fé to Black Hills, Neb., Pad.							
63	ABIES, *Tourn.*	SPRUCE; FIR.						
f	menziesii, *Lamb.*	Oregon black S.	60	Cascade mts., lat. 50°	......	Nootka, Vanc. Is.	Sierra Nevada, lat.?	OREG.
g	grandis, *Lindl.*	Yellow F.	250	......	San Francisco mt., N. M.	Columbia riv., W. T.	California?	Oreg.?
h	nobilis, *Dougl.*	Cascade mountain S.	50	Mount Hood, O. T.	San Francisco mt., N. M.	......	California	Cal.?
i	? taxifolia, *Lamb.*	Long-leaved white S.	70	......	? Roubideau's Pass, R. mts.	? Washington Ter.	? San Francisco, Cal.	Koot.?
j	williamsoni, *Newb.*	Williamson's S.	100	......	Cascade mts., lat. 44°.	......	......	Koot?
k	amabilis, *Dougl.*	Oregon silver F.	100	Columbia riv., W. T.?	Cascade mts., lat. 44°.	......	California	OREG.?
l	lasiocarpa, *Hkr.*	Downy-coned S.	......	......	......	Cascade mts., O. T.	......	Oreg.
m	bracteata, *Don.*	Leafy-coned S.	......	Mount Hood, O. T.	......	......	Coast mts., lat. 36°, Cal.	OREG.?
n	douglassii, *Sabine*	Red or black F.	250	Sierra Nevada, N. M.	Judith mts., Neb.	Lat. 52°, Russ. Am.	Coast mts., lat. 32°, Cal.	Oreg.
o	? canadensis, *Michx.*	Oregon hemlock S.	150	......	Sierra Nevada, lat.?	Russian America	......	Yukon?
64	LARIX, *Tourn.*	LARCH.						
b	occidentalis, *Nutt.*	Northwestern	150	......	Oregon Territory?	British Columbia	Lat. 43°, Cascade mts.	Koot.
65	THUJA, *Tourn.*	ARBORVITAE.						
b	gigantea, *Nutt.*	Oregon white cedar	100	......	Kooskoosky river, W. T.	......	San Diego mts., Cal.	Oreg.
c	plicata, *Nees.*	Mexican A.	......	......	......	? Nootka, V. I.	San Diego mts., Cal.	Mex.?
85	LIBOCEDRUS, *Endl.*							
	decurrens, *Torr.*	California white cedar	140	Sierra Nevada, lat. 38°	......	Lat. 41°, O. T.	San Diego mts., Cal.	CAL.

66	CUPRESSUS, *Tourn.*	CYPRESS.						
b	nutkatensis, *Lamb.*	Nootka	60	? Saskatch riv., Brit. Am.	? Mts., lat. 42°, O. T.	Norfolk Sound, Russ. Amer.	Straits of Fuca, W.T.	Yukon?
c	lambertiana ?	California { Perhaps the same as the next.	}			? Monterey, Cal.	? Mexico	Cal.
d	? lawsoniana, *Murray*							
e	macrocarpa, *Hartw.*	Long fruit cypress	60			Monterey, Cal.	San Diego, Cal.	Cal.
86	SEQUOIA.	REDWOOD.						
a	sempervirens, *Lamb.*	California	300			Coast, lat. 42°, Cal.	San Diego mts., Cal.	CAL.
b	gigantea, *Torrey.* (*Wellingtonia gigantea, Hooker.*)	Giant	450				Sierra Nevada, lat. 38°.	CAL.
68	JUNIPERUS, *Linn.*	JUNIPER.						
c	occidentalis, *Hkr.*, (*audina, Nutt.*)	Utah cedar	40	Texas	Pecos river, Tex	? Fort Colville, W. T.	Pit river, Cal.	Utah.
d	pachyphloea, *Torr.*, (*pachyderma, Torr.*)	Thick-barked J.		Zuñi mts., N. M.	New Mexico?	Gila river, N. M	Monterey, Cal.	Ariz.
e	tetragona, *Schlocth*	Square-leaved J.	15	Williams' mts., N.M.		San Felipe, Cal.		Ariz.
69	TAXUS, *Tourn.*	YEW.						
b	brevifolia, *Nutt.*, (*occidentalis, Nutt.*, in plate.)	Oregon	75		Mts., lat. 32°, Cal.	Straits of Fuca, W. T.	Downieville, Cal.	Oreg.
70	TORREYA, *Arnott.*	TORREYA.						
b	californica, *Torr.*, (*myristica, Hkr.*)	"Wild nutmeg"	75			Lat. 39°, Cal.		CAL.

C.—TROPICAL TREES OF FLORIDA AND THE GULF SHORES.

No., &c.	Botanical name.	Popular name.	Height.	Range.
87	MELICOCCA, *Linn.*	HONEY-BERRY.		
	paniculata, *Juss.*	Panicled	20	Key West.
88	CLUSIA, *Linn.*			
	flava, *De C.*	Balsam tree	30	Do.
89	GUAICUM, *Plum.*			
	sanctum, *Linn*	Lignumvitæ	40	Do.
90	SWIETENIA, *Linn.*			
	mahogani, *Linn.*	Mahogany	80	Florida.
4	ZANTHOXYLUM, *Linn.*	PRICKLY ASH.		
c	pterola, *Willd.*	....	....	Key West; Texas.
91	SIMARUBA, *Aubl.*			
	glaúca, *De C.*	Bitterwood	20?	Key West.
92	SCHAEFFERIA, *Jacq.*			
	buxifolia, *Nutt.*	Jamaica boxwood	....	Florida.
93	COLUBRINA, *Rich.*			
	americana, *Nutt.*	....	....	Key West.
94	AMYRIS, *Linn.*			
	floridana, *Nutt.*	Torch-wood	20?	East Florida.
95	BURSERA, *Jacq.*	BURSERA.		
	gummifera, *De C.*	Jamaica	[illegible]	Key West.
6	RHUS, *Linn.*	SUMACH.		
e	metopium, *Linn?*	....	....	Do.
96	XIMENIA, *Cav.*			
	americana, *Linn.*	....	15	East Florida.
97	PISCIDIA, *Linn.*			
	erythrina, *Linn.*	Jamaica dogwood	25	Key West.
98	ACACIA, *Willd.*	ACACIA.		
a	latisiliqua, *De C.*	Broad-pod	20?	Do.
99	INGA, *Willd.*	INGA.		
a	unguiscati, *De C*	Cat's claw	20	Do.
b	guadalupensis, *Pers.*	Guadalupe	....	Do.
100	PSIDIUM, *Linn.*	GUAVA.		
	buxifolium, *Nutt*	Box-leaved	20	New Smyrna; Florida.
101	CALYPTRANTHES, *Swartz.*			
	chytraculia, *De C.*	Chytraculia	20	Key West.
102	EUGENIA, *Micheli.*	EUGENIA.		
	dichotoma, *De C.*	Forked	....	Do.
	procera, *Poiret.*	Branching	....	Do.
	buxifolia, *De C.*	Box-leaved	....	Do.
103	TERMINALIA, *Linn.*			
	catappa, *Linn.*	Catappa	20	Florida.
104	CONOCARPUS, *Gaert.*			
	erecta, *De C.*	Button tree	30	Tampa Bay, Florida.
105	LAGUNCULARIA, *Gaert.*			
	racemosa, *Gaert*	....	....	Key West.
106	PAPAYA, *Tourn.*	TRUE PAPAW.		
	vulgaris, *De C.*	Custard apple	20	St. John's river, southward.
107	RHIZOPHORA, *Lamb.*	MANGROVE.		
	americana, *Nutt.*, (*mangle, Jacq.*)	American	30	Florida; Louisiana; Texas.
108	ARDISIA, *Swartz.*	ARDISIA.		
	pickeringii, *Nutt.*	Florida	30?	Lat. 28° southward.
109	ACHRAS, *Brown.*			
	zapotilla, *Nutt.*	Sapatilla	20?	Key West.

C.—*Tropical trees of Florida and the Gulf Shores*—Continued.

No., &c.	Botanical name.	Popular name.	Height.	Range.
36	BUMELIA, *Swartz.*	BUMELIA.		
d	augustifolia, *Nutt.*	Narrow-leaved	....	Key West.
e	fœtidissima, *Willd.*	....	....	Do.
110	CORDIA, *Plumier.*			
a	sebestena, *Hass*	Nocahuiteo of the Mexicans	15	Key West and Rio Grande to Salado river, Mexico.
b	floridana, *Nutt*	....	....	Key West.
111	CRESCENTIA, *Linn.*			
	cujete, *Swartz*	Calabash-tree	20?	Do.
112	AVICENNIA, *Linn.*			
	tomentosa, *Jacq.*	....	20	Tampa Bay; La.; Texas.
113	COCCOLOBA, *Willd.*			
a	uvifera, *Linn.*	Seaside Grape	60	Key West.
b	parvifolia, *Nutt.*	Pigeon Plum	....	Do.
114	HIPPOMANE, *Linn.*			
	mancinella, *Linn.*	Manchineel	80	Do.
115	EXCAECARIA, *Linn.*			
	lucida, *Swartz*	Poison-wood	20	Do.
115	DRYPETES, *Vahl.*			
a	crocea, *Poitean*	....	....	Do.
b	glauca, *Vahl.*	....	....	Do.
117	FICUS, *Linn.*	FIG.		
a	pedunculata, *Willd.*	Willow-leaved	50	Do.
b	brevifolia, *Nutt.*	Short-leaved	....	Do.
c	aurea, *Nutt.*	Golden	....	Do.

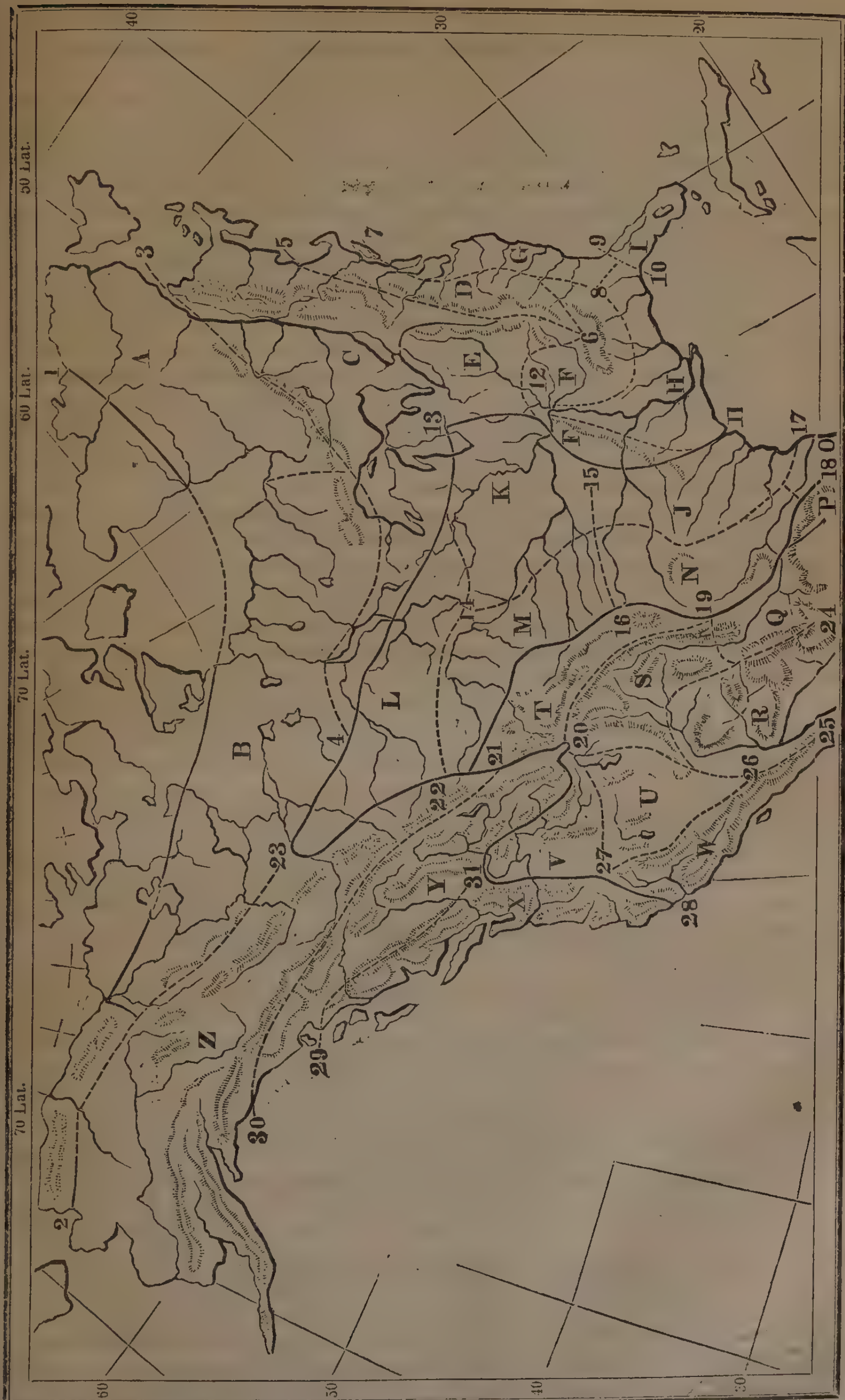
D.—MEXICAN TREES FOUND ALONG OR NEAR THE BOUNDARY.

No., &c.	Botanical name.	Popular name.	Height.	Range.
118	LARREA, mexicana, *Moric*	Hediondo	15	Gulf to San Diego mts., Cal.
73	LITHRAEA, *Walp.* laurina, *Nutt,* (*Rhus laurina, Nutt.*)	....	20	Santa Barbara, Cal.
119	PISTACIA, *Linn.*	PISTACHIA TREE.		
	mexicana, *H. B. K.*	Mexican	20	Pecos river, Texas, to San Diego, Cal.
120	SCHINUS, *Linn.*	PEPPER TREE.		
	molle, *Linn*	Peruvian	15	Rio Grande.
75	UNGNADIA, *Endl.* speciosa, *Endl*	Spanish Buckeye	....	New Braunfels, Texas, to San Pedro river, Arizona.
15	ROBINIA, *Linn.*	HONEY LOCUST.		
c	neo-mexicana, *Gray*	New Mexican	15	Mimbres river, Arizona.
121	OLNEYA, tesota, *Gray*	Palo de Hiero	....	San Pedro river to Fort Yuma, Cal.
122	PARKINSONIA, *Linn.*	PALO VERDE.		
a	microphylla, *Torr*	Small-leaved	15	San Pedro river to Fort Yuma, Cal.
b	aculeata, *Linn*	Prickly	....	(W. Indies,) Fort Yuma, Cal.
78	CERCIDIUM,	GREEN ACACIA.		
	floridium, *Benth*	Palo verde	....	San Pedro river to Colorado, Ariz.
123	ADENOSTOMA, *Hkr.* sparsifolia, *Torr*	....	30	San Diego, Cal.
98	ACACIA, *Willd.*			
b	farnesiana, *Willd,* (*cavenia, Hkr.*)	Guisache	30	(W. Indies,) Laredo to Pecos river, Texas.

D.—*Mexican trees found along or near the boundary*—Continued.

No., &c.	Botanical name.	Popular name.	Height.	Range.
124	DALEA,			
	spinosa, *Gray*		20	Colorado river, Arizona.
125	STYPHONIA, *Nutt.*			San Diego, Cal.
	integrifolia, *Nutt*		20	
127	ECHINOCACTUS, *Linn.*			
a	cylindraceus			Colorado river.
b	wislizeni, *Englm*		20?	El Paso, N. M., to Mimbres.
34	DIOSPYROS, *Linn.*	PERSIMMON.		
b	texana, *Scheele*	Japote	15	Fort Inge, Tex., to San Pedro river, Arizona.
36	BUMELIA, *Swartz.*	BUMELIA.		
f	?reclinata, *Vent.*	Spreading; Loma	30	?South Carolina to Sonora, Mex.
129	CHILOPSIS.			
	linearis, *D.C.*		25	Rio Grande to San Felipe, Cal.
130	EHRETIA.			
	elliptica, *D. C.*		30	Gulf to Chihuahua, Mex.
49	MORUS, *Tourn.*	MULBERRY.		
b	?tinctoria, *Willd*	Mora; Fustick	20	Gulf to Puerco river.
	ORNUS, *Persoon.*			
	dipetala, *Hooker*	Flowering Ash	20	Mexico and ?California.
53	QUERCUS, *Linn.*	OAK.		
*m**	acutidens, *Torr*	Sharp-toothed	20	San Luis Rey, Cal.
59	ALNUS, *Tourn.*	ALDER.		
d	oblongifolia, *Torr*	Oblong-leaved		Mimbres to Santa Barbara, Cal.
61	POPULUS, *Tourn.*	POPLAR.		
j	trichocarpa, *Torr*	Hairy-pod		Los Angeles, Cal.
65	THUJA, *Tourn.*	ARBORVITAE.		
c	plicata, *Nees.*	Mexican		San Diego mountains, (? Nootka.)
66	CUPRESSUS, *Tourn.*	CYPRESS.		
e	macrocarpa, *Hartw*	Long-fruit	60	Monterey, Cal.
f	goveniana, *Gordon*	*var.? of last*	15	San Diego mountains, Cal.
131	YUCCA, *Linn.*	YUCCA.		
	baccata, *Torr*	Fruit-bearing	25	Rio Grande, N. M., to Monterey, Cal.

* Western group.


50 Lat.
60 Lat.
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70 Lat.

EXPLANATION OF THE MAP.

This outline map of that part of America north of Mexico is intended to illustrate, so far as can be done on so small a scale, the distribution of forests, trees, &c., according to the results of the latest explorations and studies. In order to get it within the size of the page it was found necessary to make the principal meridian oblique to the sides of the map, but by noticing the corresponding numbers of the degrees of latitude the reader will easily perceive the true direction of the several points, east and west being, of course, nearly at right angles to the meridian. The equatorial projection is preferred, as showing best the true area of the various regions. The dark *full* lines crossing the continent are the outlines of the best determined and most important natural divisions, which may be called NATURAL PROVINCES. The broken lines represent approximately the subdivisions of these provinces, called REGIONS, and also parts of the province boundaries not accurately determined.

The undulations of surface, mountains, and other circumstances cause great irregularities in the outlines of regions, especially in the western part of the continent; but these are neither well determined nor, if they were, are they capable of illustration on this scale. It is believed, however, that the most marked limits are represented, that is, those by which the greatest number of species, both of plants and animals, are bounded in their range.

In using this map the reader should compare it with a good and large map of North America. The *regions* in which trees are found (indicated by letters on the map) are:

A. The *Algonquin*, in which four or five species of trees seem to be more abundant than elsewhere, and therefore *characteristic;* none, however, are *peculiar.* - - - - - -	5
B. The *Athabascan*, in which about twelve are characteristic but none peculiar - - - - - -	12
C. *Canadian*, having *seventeen* characteristic trees and *one* apparently peculiar - - - - - - -	18
D. *Alleghany*, in which there are twenty-four trees characteristic and six peculiar - - - - - -	30
E. *Ohio*, having twenty-two characteristic and *one* peculiar -	23
F. *Tennesseean*, with thirty-four characteristic and *three* peculiar	37
G. *Carolinian*, with eighteen characteristic and *seven* peculiar -	25
H. *Mississippian*, with thirty-two characteristic and *seven* peculiar - - - - - - - -	39
I. *Floridian*, with about thirty-two characteristic and thirteen peculiar - . - - - - -	45
Total number of species in the eastern forest regions - -	234

D, E, F, G, H, may be considered as forming a natural province, and called the *Apalachian.* Florida appears rather to belong to the West Indian province.

J, the *Texan*, K, the *Illinois*, and L, the *Saskatchewan* regions, are characterized by prairies; and the forests, which occur only near their eastern borders and along the rivers, gradually decreasing towards the west, are composed entirely of species characteristic of the region eastward. No new ones occur, while a large number of trees disappear at the commencement of prairies. M, the *Dacotah*, and N, the *Camanche* regions, are composed of these great treeless and often arid plains which skirt the eastern slopes of the Rocky mountains. Trees occur only in narrow belts along the rivers, and for about three hundred miles east of the mountains most of the streams are entirely woodless.

These five regions are, however, supplied with numerous peculiar plants and animals, mostly of quite distinct species from those of the forest-clad regions eastward. They are so well marked, in these respects, that, together, they may be considered as forming a natural PROVINCE, which, from its most remarkable character of plains, is called CAMPESTRIAN.

O, P, Q, may be named, from the Mexican States which partly compose them, *Tamaulipan*, *Choahuilan*, *and Chihuahuan* regions; but too little is known of them to define their limits well. Their trees are given in the list of those along the Mexican boundary, and these are found almost exclusively along the Rio Grande, within the United States. Only seven or eight species are found, in addition to the few which extend from the *Mississippi region* and Florida. - - 8

R, the *Arizonian region*, though in great part treeless, furnishes a large number of additional species, some of which are probably more common in the adjoining Mexican States of Sonora and Lower California, while others, chiefly among the San Francisco mountains, seem to be nearly or quite peculiar.

The former, thirteen in number, are included in the Mexican Boundary list, while the fourteen characteristic and *ten* (?) peculiar are in the catalogue of Western trees. - - - - - - 37

These numbers, except the total, must, however, be considered as far from settled, as the surrounding regions are but little explored, and in a region so poorly wooded, as most of it is, *ten* peculiar species could scarcely be expected. It will be remarked also, that most of these trees characteristic of the Mexican boundary are not over fifteen or twenty feet high, and in many cases these are extreme heights. Shrubs constituting the dense thickets called chapparal take the place of forests over great tracts.

S, the *Wasatch* region, almost unexplored, is not known to have any trees peculiar to it; but as the mountain summits are usually well wooded, some may be hereafter found *characteristic*, if not peculiar. 1

T, the *Padoucan*, has apparently two peculiar pines, but its vegetation is scanty in forests, and but little explored. - - 2

U, the *Utah* region, being, as far as explored, almost woodless, it is rather surprising to find that the only tree which is abundant on some of its mountains is apparently almost peculiar to it—the *Juniperus occidentalis*. - - - - - - - 1

V, the *Shoshonee* region, though, like the last, almost woodless on its plains, has some well-wooded mountain ranges, on which a larch

and several pines are found. Two willows have as yet been found only in it. One pine is believed to be more common here than elsewhere. 3

In the four last regions the place of forests is also supplied by numerous peculiar shrubs, mostly very distinct from any of the trees, as well as from the chapparal of Mexico, though some of the same genera appear as in the latter. These are not all stunted trees, but of entirely different families, and formed especially for the arid regions they inhabit. R, S, T, U, V, together, form a peculiar province, which may be distinguished as the *Rocky Mountain Province.*

W, the *Californian* region, is the most highly favored of the western groups in the variety, though not of the extent of its forests, which are confined chiefly to the mountains, while most the species occur in groups, scattered singly through the prairie. Eighteen trees are considered characteristic, and *eighteen* peculiar; making, in all, - 36

Seven others are found near San Diego, and are probably characteristic of Lower California.

X, the *Oregonian*, is densely wooded over nine-tenths of its surface, prairies occurring chiefly in the valleys of the southern part, and gradually disappearing towards the north. Thirteen trees are considered characteristic, and *nine* peculiar, though the unexplored character of the regions northward may make the number larger than it really is, 22

Y, the *Kootanic* region, is described as very densely wooded almost everywhere, and certainly that part which extends south of latitude 49° is covered with forests almost equal in size and density to those of the *Oregonian.* Eight trees are believed to be among those characteristic of it, and some will probably be found peculiar. - - 8

Z, the *Yukon* region, is believed to be generally wooded, but almost nothing is known of it or its peculiar products. Some trees have been found as far north as Kotzebue's Sound, (2) the northern limit of trees which are not known farther south, but may be Asiatic. Six of those in the catalogue are attributed to this region, as they are found only as stragglers within the boundary of the United States. - - 6

The trees of the western regions (including the Mexican boundary group) are, therefore, 131 species. The great wooded regions of the northwest—X, Y, and Z—apparently form a province distinct from those east or south of them.

W partakes of the characters of those of Lower California and Arizona, and with the former may form a province to be called the NEVADIAN. Further exploration is, however, necessary to decide their mutual relations.

Although neither time nor space will permit here a full statement of the grounds on which the dividing lines are laid down, yet a short statement of the principal ones will be necessary, in order to enable observers to collect and increase information on this interesting branch of Physical Geography. Trees represent only certain families and genera of plants, and their distribution alone would not, therefore, indicate that of other plants and of animals; but *forests* have a wonderful influence on both, and it is well known to naturalists that neither rivers, lakes, nor mountains separate the range of so many species as the line where a continuous forest skirts a woodless country.

The full line 1—2, broken towards the west, shows the northern

limit of forest growth. It is laid down from the information given by Richardson, Belcher, and other arctic explorers, and is one of the best defined boundaries of organized beings on the continent. North of it there are no trees and but few woody plants; the vegetation is mostly peculiar; and the animals, numerous in species, in but few instances extend south of it. Both are generally identical entirely around the north pole, and this therefore forms part of the *Arctic Province;* while many peculiar species as well as marked geographical boundaries separate it from the Asiatic portion and, it may be called the *Esquimaux Region.* This line coincides well with the yearly isothermal of 17° 5′, summer 50°, winter —15°, in all that portion between Hudson bay and the Mackenzie river, but it seems probable that other circumstances besides temperature regulate the forest limit near the east and west ends. Neither the climate nor vegetation of these parts is yet well enough known to admit even of speculations on this subject.

A, B, and C, may, together, be considered as forming a *Province,* which, from the number of its great lakes, may be called the *Lacustrian.* It is well characterized by its forests, almost unbroken, consisting chiefly of evergreen Corifera, which afford food and shelter to a large number of characteristic animals. It comprises most of the fur countries of North America. It is only near the Alleganies that its limits are obscure, but the broken lines there indicate the average range of its characteristic species. The next line southward is 3—4, running nearly parallel to 1—2, and separating the water-sheds of Hudson Bay and the Gulf of St. Lawrence from the basins of the Great Lakes and Lake Winnipeg. It forms the northern limit to a large number of trees, &c., but can only be considered approximate towards its eastern end. It corresponds very well with the isotherm of 37° 5′, summer 60°, winter 15°. The careful observations of Richardson at its western end show that there are about 24 species of trees common north of it, while many cease to grow very abruptly in the vicinity of Lake Winnipeg.

The country between 1—2 and 3—4 is divided for convenience into two *regions,* A the *Algonquin,* and B the *Athabascan.* Though the peculiar products of each are little known, there seem to be indications even among the trees of considerable difference, especially in the *proportions.* The Algonquin is almost unexplored, but will probably be found to have the greatest numbers of several of the trees mentioned in the catalogue, as most abundant in adjoining regions; none are, however, *peculiar* to either of these northern regions.

The line 5—6 is used to bound approximately the *Canadian Region* on the southeast, though from the nature of the country there is no well marked division there, the valleys belonging to one region and the mountains to the other.

The numbers 5—6—7 indicate the general limits of D, the *Alleghany Region* comprising the eastern slopes, and towards the south some of the highest peaks and ridges of this range; 24 trees are considered characteristic, and 6 peculiar to it. Towards the west and south its limits are not well marked from the uneven surface of the country, but to the southeast the line between it and G is the abrupt

geological boundary, between the metamorphic rocks of the hills and those of later date, corresponding to the change in soil characterizing the sandy flat low country.

The line 7—8 is the northwestern boundary of G, and a very natural one both geologically and botanically. The range of animals also corresponds to it in some degree. The boundary indicated by 9—10 is not a fixed limit, since the natural history of Florida is still but little known. There is, however, a geological line near this point, which, with the rapid increase of temperature southward, will probably be found to limit the greater number of species characteristic of Florida. The line connecting this with 8 is also only arbitrary or geographical, as it separates the waters of the Atlantic and of the Gulf. There seem to be several trees, however, limited in range near it, and probably none can be made more natural. 8—12 is a continuation of the line separating the low, sandy country from the granitic and limestone formations of the hilly country. From 12 it extends southwest, bordering the hilly table-land west of the Mississippi valley.

The *broken* line 6—12 is one of the most unsettled of all. Though a number of trees are limited in this vicinity, there is no geological or geographical line by which they may be bounded, and an attempt is therefore made to make an *average* limit, depending on climate and elevation as well as on the actual facts of distribution.

An eminent geologist has suggested to me that perhaps the southern limit of the *drift* may be found the true boundary here and on the line of 15—16.

The lines G—6—15—16 may represent the summer isothermal of about 75°, while 7—6—15—16 are near that of 35° for winter and 55° for the year.

The numbers 11—15—13 indicate the eastern border of prairies, and the limit of the great number of plants and animals which belong exclusively to them. It is one of the best marked of all the lines, though, since the settlement of the country, it has become obscured both by the extension of forests westward and their destruction eastward of it. The line represents nearly its natural position. The figures 13—23 show the northeastern border of the prairies, which is considered pretty well established, as far as authorities examined give any data for it. Richardson mentions their northern extremity near Great Slave lake.

The line 13—14—22 is a good geographical boundary, and also nearly coincides with the isothermal of summer 70°, though winter seems to differ much at its two extremities. 14—18 is the line of about 2,000 feet general elevation, and west of which scarcely any of the eastern trees extend; in all not over six or eight species, while, as already stated, most of M and N is entirely woodless.

The numbers 17—18 show approximately the boundary of the tropical group of animals and plants which are found on the lower Rio Grande. On a larger map the direction of this line would be more irregular in detail.

The numbers 18—19—16—21—22—23 mark the line limiting the forests and other products of the western mountains. It will be found

a very well marked, though irregular, boundary, and of trees only two or three western species extend east of it, and as many eastern ones westward. The general elevation of the country on this line is from 3,000 to 4,500 feet, and the sudden change from plains to mountains causes a corresponding change in climate, productions, and general features.

The line 19—20—21 is a geographical boundary, which, from the great elevation of the dividing ridge, and the different climates of its opposite sides, causes a more marked limitation here than on most of the other western mountains.

The line 24—26—25, provisionally bounding the Arizonian region, is founded chiefly on the isothermal lines. The great summer heat of 80° and upwards is connected with the growth of the *Cactaceae* and other peculiar plants, and the mountains between the Colorado and Gila also have many peculiar forms even on their cool, high summits; and 26—20, bounding the upper Colorado valley, is the geographical boundary of the Wasatch region on the west.

26—27 and 20—27 form the geographical boundaries of the Utah basin; and the latter appears also to be near the summer isotherm of 75°. The whole of this region is more than 4,500 feet above the sea.

20—31—27 forms the northern boundary of the great Columbian plains or Shoshonee region, and is also a well marked limit of the continuous forests northward of it. It coincides also pretty well with the summer temperature of 70° and 35° for winter, or 45° annually. The sudden change in the surface by forests causes these isothermals to be more abrupt than in a country uniformly bare or wooded. This is probably the *effect* of increased rains, which, of course, affect other products also. For this reason it is believed that the summer temperature of about 65° will be found to run along the line of 13—4—23, instead of being parallel to 70° on 13—14—22.

26—27—31 is the eastern limit of the continuous forests of the Sierra Nevada and Cascade ranges, and a very good natural boundary. 27—28 is the approximate limit between W and X, and though in reality very irregular from the rough character of the country, its general direction is sufficiently shown. It limits the range of many trees and other products.

A boundary probably exists between Upper and Lower California, but cannot yet be determined naturally.

The broken lines 31—29, 21—30, 23—2, are of course merely conjectural, but are made to correspond to the general features of the country as well as the direction of the isothermal lines. On the coast at 30° the annual temperature is as high as 43° 5′, corresponding to that of the coast of Maine; while what little is known of the interior shows that though exceedingly rugged and often inaccessible the Yukon region possesses a good climate and a great variety of natural products, probably comparable with Sweden and Norway. Its winters are milder near the coast than those of Maine, though fifteen degrees farther north.

These few notes, hastily thrown together, will, it is hoped, make the design intelligible, and lead others to investigate and increase our very imperfect knowledge of animal and vegetable distribution. The

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writer has collected a large amount of material relating to it, which he hopes at some future time to publish in the form of physical charts, and intends the present paper merely as a circular requesting further information, for which due acknowledgment will always be made, and the favor reciprocated as far as possible.

GENERAL CONCLUSIONS.

Looking now at the regions as combined in groups, we may derive the following conclusions from the examination of the number of species, abundance and arrangement of their trees and forests.

1st. Coming southward from the treeless Esquimaux region and passing a certain well marked line, we suddenly find a continuous forest, broken only where the poverty of the soil or other local causes prevent the growth of trees. About fifteen species compose this forest, but the prevailing forms are the Coniferae. For much interesting detail on the influence of climate and other causes on this northern line, as well as for evidence of its encroachment southward, I must refer the reader to Dr. Richardson's interesting Arctic explorations.

Passing into the Canadian region we find seventeen species of trees suddenly added as characteristic, and towards its southern border many of those of the Apalachian Province begin to appear. Yet the Lacustrian Province is a well marked one, and in the grouping of its trees differs materially from those farther south.

Too little is known of the climate, in its interior especially, as to the amount of rain at different seasons, to form conclusions as to its influence on this peculiar grouping. It appears more probable that other physical agents were the chief ones in this respect, particularly the geographical and geological barriers which those interested may perceive on good maps. Another affecting the western part of the boundary will be hereafter referred to.

2d. Coming next to the Apalachian Province, and remembering that the forests of a great part of the Alleghenies are only a southward extension of those farther north, we find a vast increase in the variety of our forest trees. In fact, looking at all its natural products collectively, one of the most striking, as compared with the rest of the world between the 30th and 45th degrees of north latitude, is its richness in trees, which will compare favorably with almost any part of the tropics.

It contains more than twenty species which have no representatives in the temperate climates of the Old World, and a far greater number of species of the forms found there. In fact, those trees which have been considered characteristic of the Lacustrian Province, with perhaps the addition of those of the Allegheny region, will fully represent all the common trees of Europe in number of species, though a few other genera must be added from other regions to give them all.

Yet with all this variety the bulk of the Apalachian forests is of forms characteristic of the temperate zone. Only about twenty-three out of one hundred and thirty-six species are *broad-leaved* evergreens, and these nearly all in the two southern regions. We will hereafter see a marked difference in another part of the continent in this respect,

and I will merely allude to its connexion with, though *not dependence* on, the peculiarities of our climate. We have with a tropical summer a tropical variety of trees, but chiefly of northern forms. Again, with our arctic winters we have a group of trees, which, though of tropical forms, are so adapted to the climate as to lose their leaves, like the northern forms, in winter. But here, it must be distinctly understood, is no alteration *produced* by climate. The trees were made for and not *by* the climate, and they keep their characteristics throughout their whole range, which with some extends through a great variety of climate. I will not stop to discuss the relations of *specific distinctions* and external physical influences, assuming that the reader understands the scientific views of the subject. Besides the connexion between the winter climate and the deciduous trees, we find a remarkable instance of a similar character in the great forests of pines which appear in our subtropical southern borders, and with them a cypress, chiefly a subtropical form of the Coniferae, which, unlike all others, loses its leaves in winter like northern trees. Thus, as our climate shows great extremes, so do the forms of vegetation adapted for it; and the very wide distribution of many of these forms may be considered by some a proof of the great past duration of the same climate, on the supposition that each species has spread slowly from a narrow *centre of creation*.

Another marked climatic connexion is that of the *moisture* annually deposited on this province. I need not prove to those who have studied the subject that this is one of the most essential elements for the growth of forests of all kinds of trees. The dense growth of the ever-rainy tropics in some parts of the world, with the bare plains or deserts of other equally tropical countries which have little or no rain, prove that heat alone has little influence. On the other hand, our Lacustrian Province is densely wooded almost to the limits of perpetual frost, while the Steppes of Siberia, though of similar temperature, have little or no wood, being supplied with little moisture. Other proofs will be referred to hereafter. But besides the total amount, the equal distribution of the rains is important, as will be seen when we speak of regions having a dry and a wet season alternately.

Without going further into this interesting subject here, I will say that I believe the reader, upon close study of it, will come to the conclusion that so intimate a relation exists between the trees and the climate of this Apalachian Province that their peculiarities always have and always must exist together. The disadvantages we feel in the climate are in this way compensated for, and will in time be looked upon as among the greatest natural advantages of the country. The midday heat, by rarefaction and evaporation, brings northward from the Gulf its abundant moisture. After several hours or days the cold westerly or northerly wind condenses this in rain over all that part of the continent included in this province, and in a less amount for some distance west and north of it. Thus in summer a continual supply is provided, while in winter the same winds which condense the summer rains become our most dreaded arctic blasts.

The Lacustrian Province does not derive much moisture from the Gulf winds, but while its colder climate makes evaporation slower, it receives a share both from its own waters and probably also from the

Pacific, as is shown by Lieutenant Maury in his Physical Geography of the Sea, though he makes the rains come down entirely too far to the south in regions known to receive but little.

3. A few words on Florida will show its peculiarities in relation to trees and climate. The trees of Georgia extend for a long distance, some of them continuing as prevailing forms almost to its extremity. But they are gradually replaced by more tropical species, although where the most marked line of distinction exists is not well known. Most of those in the special list have been yet found only on Key West, but the examination of the almost unexplored interior, especially the Everglades, will doubtless extend their range materially. Forty-eight out of seventy-eight species found in it are evergreen, and all but four of these the broad-leaved tropical forms.

Towards the middle of the State are found extensive prairies and treeless tracts, which are evidently connected with the alternation of wet and dry seasons, generally well marked in its climate. Though the wet season is in summer, yet the little interruption of growth by cold at other seasons makes their dryness influential. Its effects will be hereafter more fully alluded to.

4. Now coming to the CAMPESTRIAN PROVINCE we find, as already stated, that no new forms of trees appear, while those found rapidly diminish and disappear towards the west. Thirteen species have not been traced west of its eastern border; about ninety extend pretty far into the *Texan* and *Illinois* regions, but only five or six get across the eastern limit of the Camanche and Dacotah regions, which, however, receive nine or ten more from the west and north.

The *Saskatchewan* region, bordering close upon the well-wooded Lacustrian Province, may have a few more eastern species, and possibly more from the west, as there is evidence that it is better watered and approaches in character to the Illinois region.

It will be observed that the southeast and northeast borders of this province form nearly a right angle with each other, and extending east into Michigan cause a wide separation of the Lacustrian and Apalachian provinces. This is one of the most well defined facts in the distribution of trees. A careful examination of the minute land office surveys has shown that the line is exceedingly distinct in Wisconsin and Minnesota, prairies prevailing to the south of it interspersed with oak-openings and groves of deciduous trees along the streams, while to the north pine and spruce forests with tamarack swamps cover the whole country, having the other *Canadian* trees with them. This is doubtless in great part due to the change in the character of soil and of the underlying rocks, which retain the moisture, while it is completely drained off to the south. Thus we have here a distinct division of the two eastern forest provinces, assisting to determine where it would be eastward were it not disguised by local irregularities of surface.

The cause of the disappearance of trees in the Campestrian Province is, in a word, the deficient and irregular supply of moisture. I need not enter into the proofs of this, but refer to the records of meteorologists. It is true that this does not materially affect agriculture in the more eastern regions; in fact, most crops will succeed better with

less rain than is necessary for most trees to thrive, and in some years there is even a greater supply of rain in the Texan and Illinois regions than eastward. But there are years and series of years of drought, when in their natural condition the forests take fire from the slightest cause and burn over large tracts. This was made even more general by the Indians, but since the white settlement has in great degree ceased and forests have been re-established. In the Apalachian region droughts have never been sufficient to keep trees from extending themselves as soon as a forest might be partially destroyed by fire, and thus the formation of prairies has been prevented. A consideration of the source of the rains will explain why the limit of prairies has its present direction. Coming north from the Gulf they are continually carried more and more eastward by the westerly winds; and as the greater part of the moisture is precipitated before reaching the Ohio river, the Illinois region is deprived *for many* years of its due share of rains.

The Texan region lying quite west of the line of travel of those Gulf streams has to depend on less abundant sources for its rains. Now, as we go westward the supply rapidly diminishes until in the Camanche and Dacotah regions it is entirely inadequate to the growth of trees as well as of most cultivated products; and in some parts even grass and other herbage entirely disappear over vast tracts. From the great bend of the Missouri north, however, there seems to be an improvement in the country. On the banks of that river, above Fort Union, there is no long interval without trees as there is farther south on nearly all the streams, and on the Saskatchewan there is even less.

The very porous character of the soil and underlying rocks assists much in this aridity of the country, and we therefore find that the line marking the junction of the carboniferous rocks of the Illinois region with the cretaceous and tertiary is a distinct limitation of many trees.

When better known the geological character will help much in defining the physical geography of the surface of this province. In Texas the border of the Llano Estacado coincides with that of the Camanche region for a long distance. It is evidently more the retentiveness of the soil than its mineral composition that affects the growth of trees, for all soils contain more or less of their essential ingredients.

Even the saline substances, which are supposed by some to make deserts of portions of the Great Plains, are rather the secondary effects of the climate; for if rains were abundant these salts would become diffused, and in their proper proportions enter into the structure of trees and other plants.

It is certain, however, that even if the fires cease very few trees will ever be made to grow in these two arid regions.

5. Coming now to what I have called the Rocky Mountain province, we find that the relations of climate and forest characteristic both of the Campestrian and Apalachian provinces are repeated, but combined in an entirely new manner.

The high mountain ranges resemble the latter in their regular supply of rain, while near their summits the vegetation of the *Athabascan* region appears either in identical or allied forms, and still higher,

near the limits of perpetual snow, the *Esquimaux* vegetation is almost precisely copied. But, on the other hand, the lower plains present every shade of succession, from the continuous forests of the Apalachian, through the rich prairies of the Illinois, to the barren deserts of the Camanche region. All these characteristics occur, however, in comparatively narrow belts surrounding isolated peaks or ranges, and the species of trees met with are nearly all distinct from those of the eastern provinces.

Another distinctive character is in the fact that this province receives its rains from the west, (except, perhaps, some of the most eastern mountain slopes and those of Arizona,) and the supply of moisture is in direct proportion to the vicinity of any region to the Pacific, and the obstacles between it and that reservoir. Thus the Sierra Nevada cuts off almost all the rain from Utah, the little that reaches its eastern part being from local evaporation and what is intercepted by the lofty central ranges from the higher currents of the atmosphere.

It thus happens that no constant elevation and no similar exposure has always the same amount of forest or other vegetation; local circumstances make every range of mountains and every valley differ somewhat from those around it.

But, as a general fact, we find that those *regions* towards the *north* are the best supplied with moisture, and therefore best wooded—exactly contrary to the character of those regions which receive their moisture from the Gulf of Mexico.

Near the Mexican boundary we enter the belt of *rainless* regions described by Lieutenant Maury; and here the supply is indeed precarious, though apparently more adequate to vegetation than in the Utah region.

Although I have enumerated a long list of trees as first appearing on this line, it is in reality, for the most part, a *treeless* belt. Scattered individuals of numerous species occur, often limited to one narrow locality, as if merely outlines of more extensive forests in Mexico, or of what were once more extensive here, and have been destroyed by drought. Lieutenant Ives found great tracts of some of the more common trees thus standing dry and dead, as if killed within a recent period; but this is not the place to discuss these apparent changes in the climate of the country.

The higher San Francisco and other ranges seem, however, to receive a better supply of moisture from the upper strata of the air, while their more impervious rocks probably retain it, and their cool summits condense around them enough moisture for the leaves of trees. I may remark here, that it would seem as if trees, rising high above the surface of the ground and expanding a vast evaporating surface of leaves to the air, require a greater degree of moisture *in the air* than herbaceous plants. They cannot, like the herbs of all arid regions, dry up and die down to their roots, to spring again with the wet season; they must retain vitality throughout or die. This constitutes a real physiological distinction between trees and herbs. The shrubs which live in those arid regions, presenting less evaporating surface, and having larger rootstocks in proportion, withstand droughts.

6. The *Californian* region stands alone, unless combined with the

Peninsula by natural affinities. Its mountains essentially resemble in climate and forest growth the Lacustrian province. Its valleys are like the Illinois and Texan regions, with this difference: that they have periodic dry and wet seasons, occurring at seasons opposite to those of Florida. Connected with this and with the mildness of its winters we again find a large proportion of broad-leaved evergreens, several genera, as the oaks and chestnut, which are deciduous in the east, being nearly all evergreen there. I should have mentioned that the same is the case in Arizona, though there a climate of tropical heat requires no interruption of vegetation.

7. The *Oregon* region, and those north of it, as far as known, have very peculiar characters as well as points of resemblance to the eastern region. The climate is mild and equable, without excessive heat or cold, the rains abundant, and towards the coast excessive, with but short intervals, scarcely amounting to a dry season. The forests, while mostly composed of the northern forms of Coniferae, have also several broad-leaved evergreen trees and shrubs, which give them almost a tropical aspect. Both in climate and vegetation this western coast resembles much the coast of Europe, species and genera of trees being almost identically represented, and in about the same numbers. On the other hand, a similar analogy exists between the Apalachian forests and those of China.

The marked differences in the character of the various mountains and valleys in these western regions may in future lead to more minute division than I have adopted, but present information does not warrant it now. Species formerly supposed to be limited to a narrow district have unexpectedly been found in others far distant, but of similar natural character, the intervening wide tracts being entirely destitute of them. Many facts go to show that the distribution of trees and forests was once very different, and is even now constantly changing, together with the climate; but as even the possibility of this change is doubted by some, except with such geological convulsions as can upheave mountains and sink continents, we must not be hasty in deciding the question.

It may be objected to what I have said of the connexion between the cold winds and the constant rains of the Apalachian province that they do not coexist in the northwestern regions, which, together, form the Caurine Province. But there are other causes which produce the precipitation of rain there. One is the cold *northwest* sea-breeze, which in winter precipitates the moisture brought by the *southwest* winds; the other is the cold air around the peaks of perpetual snow, which in summer produces at night a downward cold current with the same condensing effect.

Thus the snowy mountains assist to improve the climate, and intercept much of the rain which, more to the north, seems to pass over the lower mountain ranges and to reach the Lacustrian province.

Much more might be said respecting the connexions of forests and climate, but the general and best known facts are presented so as to lay the way for more complete observations. The provinces and regions may be classified in the following manner as to these connexions:

A.—Completely wooded; rains equally distributed and abundant.—*The Lacustrian and Apalachian.*

B.—Partially wooded; rains sometimes deficient.—*Florida, Texas, and Illinois regions.*

C.—Almost woodless; rains always deficient.—*Dacotah, Camanche, and Utah regions.*

D.—Plains and valleys unwooded; mountains wooded in proportion to their moisture, which is irregularly distributed, or periodical.—*Rocky mountain province, except Utah?*

E.—Partially wooded; rains periodical.—*Californian region and Mexican province?*

F.—Nearly all densely wooded; rains somewhat periodic, increasing in amount to the north, and with elevation.—*Caurian province.*

From what examination I have been able to give the subject, I conclude that at least fifteen inches of rain *during the growing season* is essential to the vegetation of trees of all kinds. This, however, must vary with the retentiveness of the soil, the rapidity of evaporation, and the species of tree, some requiring much more than this. We have seen that, with its abundant moisture at all seasons, the Apalachian province has far the greatest number of species of trees, while the *Caurian*, though with perhaps *more* rain, unequally distributed, has much fewer. This is, however, connected also with its cooler summers, and, as before remarked, we have in the east a tropical forest with our tropical summers, in spite of arctic winters.

From an accurate determination of the range of trees much interesting information on both climatic and other physical influences is expected to be derived. At the same time the distribution of all other plants and of animals must be studied in order to arrive at a knowledge of that harmonious system which undoubtedly prevails throughout the organic world, however obscured by the accidents of time and of external influences. Among them all we believe that *forests* will be found one of the most important, and respectfully invite the attention of the reader to its investigation.

LIST OF BIRDS OF NOVA SCOTIA.

Compiled from notes by Lieutenant Blakiston, R. A., and Lieutenant Bland, R. E., made in 1852—1855, *by Professor J. R. Willis, of Halifax.*

[N. B.—The species with an asterick (*) prefixed are inserted on the authority of Andrew Downs, esq. The nomenclature is that of Audubon's synopsis.]

Bald-headed Eagle, (*Haliœtus leucocephalus.*) Resident; not uncommon.

Osprey, (*Pandion haliœtus.*) Common along the coast; breeds.

*Ice Falcon, (*Falco islandicus.*) Very rare and only in winter; one instance in ten years.—(A. Downs.)—? ? ? J. R. W.

Pigeon Hawk, (*F. columbarius.*) Common; breeds.

Sparrow Hawk, (*F. sparverius.*) Not uncommon; breeds.
Red-shouldered Buzzard, (*Buteo lineatus.*) Rather common; breeds.
Rough-legged Buzzard, (*B. lagopus.*) Rare.—? ?
Red-tailed or American Buzzard, (*B. borealis.*) Not common.
American Goshawk, (*Astur atricapillus.*) Rather common.
Sharp-shinned Hawk, (*A. fuscus.*) Rather common.
American Hen Harrier, (*Circus hudsonicus.*) Abundant; breeds.
Hawk Owl, (*Strix funerea.*) Common; breeds mostly north.
Snowy Owl, (*S. nyctea.*) Rare here in winter; breeds north.
Long-eared Owl, (*S. otus.*) Not common.
Short-eared Owl, (*S. brachyotus.*) Not common.
Acadian Owl, (*Noctua acadica.*) Resident; common.
Tengmalm's Owl, (*N. tengmalmi.*) Rare; resident inland.
Sparrow Owl, (*N. passerina.*) Found inland; very rare.
Barred Owl, (*Syrnium nebulosum.*) Resident; common.
Great horned Owl, (*Bubo virginianus.*) Resident; very common.
Whip-poor-will, (*Caprimulgus vociferus.*) Rare; arrives beginning of June.
Night Hawk, (*C. virginianus.*) Abundant; arrives end of May; breeds.
Chimney? (American?) Swallow, (*Hirundo pelasgia?*) Arrives end of March.
*Purple Martin, (*H. purpurea.*) Occasional.
White-bellied Martin, (*H. bicolor.*) Abundant; arrives about 20th April.
Republican or Cliff Swallow, (*H. fulvas.*) Abundant; arrives about 1st May; departs about the 20th August.
Barn Swallow, (*H. rustica.*) Abundant; arrives about 1st of May; departs beginning of September.
Bank Swallow, (*H. riparia.*) Inland.
Belted Kingfisher, (*Alcedo alcyon.*) Common; arrives about 1st of May; departs middle of September.
Tyrant Flycatcher, (*Musicapa tyrannus.*) Common inland; breeds.
Green-crested Flycatcher, (*M. acadica.*) Not common.
Wood Peewee, (*M. virens.*) Not common.
American Redstart, (*M. ruticilla.*) Abundant; arrives about 10th May.
Least Peewee, (*M. pusilla.*)
Great American Shrike, (*Lanius borealis.*) Not common; resident during winter.
Migratory Thrush or Robin, (*Turdus migratorius.*) Abundant; arrives middle of April.
Hermit Thrush, (*T. solitarius.*) Arrives 1st May; abundant; nests on the ground.
Olivaceous Thrush, (*T. olivaceus.*) Not common; nests in bushes.
Cat Bird, (*T. felivox.*) Common inland; arrives 1st June.
Golden-crowned Thrush, (*T. aurocapillus.*) Common; arrives about 10th May.
*Water Thrush, (*Cinclus americanus.*) Inland; rare.
American Pipit, (*Anthus ludovicianus.*) Arriving in flocks about 20th September; goes south.

Canada Flycatcher, (*Myiodioctes canadensis.*) Common inland; arrives about 10th May.

Wilson's Blackcap, (*M. wilsonii.*) Inland; not common; arrives about 10th May.

Yellow-rump Warbler, (*Sylvicola coronata.*) Abundant; arrives about 24th April.

*Black-poll Warbler, (*S. striata.*) Rare.

Bay-breasted Warbler, (*S. castanea.*) Rather rare; arrives about 10th May.

Chestnut-sided Warbler, (*S. icterocephala.*) Common; arrives about 10th May.

Hemlock Warbler, (*S. parus.*) Resident in autumn; departs in November.

Black-throated Green Warbler, (*S. virens.*) Very rare; one instance only.

*Cape May Warbler, (*S. maritima.*) Abundant; arrives about 10th May.

Blackburnian Warbler, (*S. blackburnia.*) Not uncommon inland.

Yellow-poll Warbler, (*S. aestiva*) Common; arrives about 5th May.

Red-poll Warbler, (*S. petechia.*) Very common; arrives about 23d April.

Yellow-back Warbler, (*S. americana.*) Inland in hard woods; rare.

*Black-throated Blue Warbler, (*S. canadensis.*) Rare.

Black and yellow Warbler, (*S. maculosa.*) Abundant; arrives about 10th May.

*Blue-green Warbler, (*S. coerulea.*) Very rare.

*Mourning Warbler, (*Trichas philadelphica.*) Very rare.

Maryland Yellow-throat, (*T. marilandica.*) Abundant.

Nashville Warbler, (*Sylvicola rubricapilla.*) Rare.

Black and White Creeper, (*Certhia varia.*) Common; arrives about 10th May.

Winter Wren, (*Troglodytes hyemalis.*) Inland; not common.

American Goldcrest, (*Regulus satrapa.*) Resident; common.

Ruby-crowned Wren, (*R. calendula.*) Not common.

Blue Bird, (*Sialia wilsonii.*) Occasional.

Brown Creeper, (*Certhia familiaris.*) Resident; common.

Blackcap Tit, (*Parus atricapillus.*) Abundant; resident.

Hudson Bay Tit, (*P. hudsonicus.*) J. R. W.

Solitary Vireo, (*Vireo solitarius.*) Not common.

Warbling Vireo, (*Vireo gilvus.*) Rare.

Red-eyed Vireo, (*Vireo olivaceus.*) Very common; arrives about 10th May.

Cedar Bird or Waxwing, (*Bombycilla carolinensis.*) Arrives in flocks 1st June; leaves end of August.

Shore Lark, (*Alauda alpestris.*) Arrives from north middle of October; returns from south 20th March.

Fox-colored Sparrow, (*Fringilla iliaca.*) Breeds north; arrives in December going south; returns 15th March.

Song Sparrow, (*F. melodia.*) Earliest singing bird, 14th March; goes south with Warblers.

White-throated Sparrow, (*F. pennsylvanica.*) Arrives beginning of April; abundant.

Bay-winged Sparrow, (*Emberiza graminea.*) Very rare.

Chipping Sparrow, (*E. socialis.*) Inland.

Tree Sparrow, (*E. canadensis.*) Common here in winter; breeds north.

Snow Bird, (*Niphoea hyemalis.*) Very abundant; arrives 1st of April; leaves 20th October.

Swamp Sparrow, (*Fringilla palustris.*) Not uncommon; arrives 1st May.

American Lesser Redpole, (*Linaria minor.*) Abundant, in flocks, during autumn.

Pine Finch, (*L. pinus.*) Probably resident.

Purple Finch, (*Fringilla purpurea.*) Very common; arrives about 27th March.

Savannah Sparrow, (*Emberiza savanna.*) Abundant; arrives 10th June; departs 15th September.

Snow Bunting, (*E. nivalis.*) In flocks; arrives about 1st November; departs about 20th March; breeds north.

*Indigo Bird, (*Fringilla cyanea.*) Accidental; have been one or two instances.—(? J. R. W.)

American Goldfinch, (*Carduelis tristis.*) Inland; rare.

Pine Grosbeak, (*Corythus enucleator.*) Here in winter; some years abundant; breeds north.

Common Crossbill, (*Loxia curvirostra?*) Resident.

White-winged Crossbill, (*L. leucoptera.*) Resident; common.

Rose-breasted Grosbeak, (*Coccoborus ludovicianus.*) Inland; rare.

*Scarlet Tanager, (*Pyranga rubra.*) Accidental.

Bobolink, or Rice Bunting, (*Emberiza oryzivora.*) Common inland; arrives about 1st May.

*Cow Blackbird, (*Molothrus pecoris.*) Occasional.

*Red-winged Blackbird, (*Agelaius phœniceus.*) Inland; occasional.

Common Crow Blackbird, or Purple Grackle, (*Q. versicolor.*) Rare.

Rusty Grackle, (*Q. ferrugineus.*) Common; arrives 17th March; departs about 20th October.

Boat-tailed Grackle!! (*Quscalus major.*) Rare; only specimen I have seen was shot by A. Downs, esq., last summer, and is now in a case of birds belonging to Sir Gaspard Le Marchant.—J. R. Willis.

Raven, (*Corvus corax.*) Resident; not common.

American Crow, (*Corvus americanus.*) Resident; common.

*Fish Crow, (*C. ossifragus.*) Resident; rare.

Blue Jay, (*Garrulus cristatus.*) Resident; (?) abundant.

Canada Jay, (*G. canadensis.*) Resident; abundant.

*White-breasted Nuthatch, (*Sitta carolinensis.*) Autumn and winter; not common.

Red-bellied Nuthatch, (*S. canadensis.*) Common in winter; inland.

*Brown-headed Nuthatch, (*S. pusilla.*) Very rare.

*Meadow Lark, (*Sturnella ludoviciana.*) Very rare; inland; one instance.

Ruby-throated Humming Bird, (*Trochilus colubris.*) Abundant; arrives beginning of April; departs about the 20th September.

Pileated Woodpecker, (*Picus pileatus.*) Inland; rare; resident.

Hairy Woodpecker, (*P. villosus.*) Very common; resident.

Downy Woodpecker, (*P. pubescens.*) Common; resident.

Yellow-bellied Woodpecker, (*P. varius.*) Inland; not common; migrates.

Arctic Three-toed Woodpecker, (*P. arcticus.*) Rather rare; resident.

Golden-wing Woodpecker, (*P. auratus.*) Common; arrives about 1st May; departs in November.

*Black-billed Cuckoo, (*Coccyzus erythropthalmus.*) Very rare.

Yellow-billed Cuckoo, (*C. americanus.*) Rare; arrives about 1st June; breeds.

*Carolina Long-tailed Dove, (*Ectpiestes carolinus.*)

Passenger Pigeon, (*Columba migratoria.*) Sometimes very abundant; arrives about end of July.

Ruffed Grouse, (*Tetrao umbellus.*) Abundant; resident; young fly about 20th August.

Canada Grouse, (*T. canadensis.*) Not very common.

American Coot, (*Fulica americana.*) Not common; depends on setting in of the frost; 1st to end of November.

Yellow-breasted Rail, (*Rallus noveboracensis.*) Rare; depends on setting in of the frost; 1st to end of November.

Sora Rail, (*R. carolinus.*) Not common; depends on setting in of the frost; 1st to end of November.

American Bittern, (*Ardea lentiginosa.*) Very common; leaves end of October.

*Least Bittern, (*Ardea exilis.*) Accidental.

Great Blue Heron, (*A. herodias.*) Common; breeds.

Snowy Heron, (*A. candidissima.*) Very rare.

American Golden Plover, (*Charadrius marmoratus.*) Arrives in flocks 15th August.

Piping Plover, (*C. melodus.*) Rare.

Black-bellied Plover, (*C. helveticus.*) Not common; arrives in August; leaves in October.

American Ring Plover, (*C. semipalmatus.*) Abundant; arrives in August; leaves in October.

Turnstone, (*Strepsilas interpres.*) Not common.

Ash-colored Sandpiper,† (*Tringa islandica.*) Abundant; August and September.

Red-backed Sandpiper, (*T. alpina.*) Abundant; August and September.

Semi-palmated Sandpiper, (*T. semipalmata.*) Abundant; August and September.

Little Sandpiper, (*T. pusilla.*) Abundant; August and September.

Pectoral Sandpiper, (*T. pectoralis.*) Rare.

Schinz's Sandpiper, (*T. schinzii.*) Not common.

Sanderling Sandpiper, (*T. arenaria.*) Abundant; August and September.

*Willet, (*Totanus semipalmatus.*) Very rare; breeds.

Spotted Tattler, (*T. macularius.*) Common; arrives beginning of May; breeds.

Solitary Tattler, (*T. solitarius.*) Common.

Yellow-shanks, (*T. flavipes.*) Abundant; arrives beginning of July; leaves by end of August.

Tell-tale, (*T. vociferus.*) Abundant; arrives later; leaves end of October.

Hudsonian Godwit, (*Limosa hudsonica.*) Common; arrives about 15th September; leaves end of October.

Curlew Sandpiper, (*Tringa subarquata.*) Not common.

American Snipe, (*Scolopax wilsonii.*) Common; arrives end of March.

Red-breasted Snipe, (*S. noveboracensis.*) Common; August and September.

American Woodcock, (*Microptera americana.*) Common; arrives about 17th March; leaves about the end of October.

Hudsonian Curlew, (*Numenius hudsonicus.*) Common; August and September.

*Long-billed Curlew, (*N. longirostris.*) Very rare.

Esquimaux Curlew, (*N. borealis.*) Not common.

Grey Phalarope, (*Phalaropus wilsonii.*) Rare.

Canada Goose, (*Anser canadensis.*) Passes north 17th March; returns 15th October.

*Brent Goose, (*A. bernicla.*) Rare.

*Snow Goose, (*A. hyperboreus.*) Occasional.

Mallard Duck, (*A. boschas.*) Rare.

Dusky Duck, (*A. obscura.*) Abundant; breeds; resident.

Gadwall, (*A. strepera.*) In winter; rare.

Pin-tail Duck, (*A. acuta.*) In winter; common; breeds north.

American Wigeon, (*A. americana.*) Not common; winter.

Summer Duck, (*A. sponsa.*) Arrives about middle of March; breeds; rare.

American Green-winged Teal, (*A. carolinensis.*) Common; leaves about middle of October.

European Green-winged Teal, (*A. crecca.*) One killed here in September, 1854.

Blue-winged Teal, (*A. discors.*) Not common; here in September; breeds north.

*Shoveller Duck, (*A. clypeata.*) Very rare; breeds north.

Scaup Duck, (*Fuligula marila.*) Autumn and spring; not common.

Ring-necked Duck, (*F. rufitorques.*) Rare; breeds in lakes inland.

Ruddy Duck, (*F. rubida.*) Very rare.

*Pied Duck, (*F. labradora.*) Occasional.

Velvet Scoter, (*F. fusca.*) Common; goes north to breed; here in winter.

Surf Scoter, (*F. perspicillata.*) Not very common; breeds north as well as inland.

American Scoter, (*F. americana.*) Abundant; breeds north.

Eider Duck, (*F. mollisima.*) Abundant in winter; breeds north.
Golden-eye Duck, (*F. clangula.*) Abundant in winter.
Buffle-headed Duck, (*F. albeola.*) Common; breeds north.
Long-tailed Duck, (*F. glacialis.*) Abundant in winter.
Harlequin Duck, (*F. histrionica.*) Common in winter.
*King Eider Duck, (*F. spectabilis.*) Has been seen here; very rare.
Goosander, (*Mergus merganser.*) Common; resident; breeds on the lakes.—(? J. R. W.)
Red-breasted Merganser, (*M. serrator.*) Common, resident; breeds on the lakes.
Hooded Merganser, (*M. cucullatus.*) Very rare.
Common Gannet, (*Sula bassana.*) Common of the coast.
Common Tern, (*Sterna hirundo.*) Abundant; breeds here.
Bonaparte's Gull, (*Larus bonapartii.*) Not uncommon in autumn.
Black-headed Gull, (*L. atricilla.*) Rather rare.
Kittiwake Gull, (*L. tridactylus.*) Very common.
Herring Gull, (*L. argentatus.*) Common.
*Common American Gull, (*L. zonorhynchus.*)
Black-backed Gull, (*L. marinus.*) Common; breeds in Labrador.
Mother Cary's Chicken, (*Thalassidroma pelagica.*) Common off the coast.
Least Petrel, (*T. wilsonii.*)
Common Puffin, (*Mormon arctica.*)
Little Auk, (*Mergulus alle.*) Rather rare.
Razor-bill, (*Alca torda.*)
Common Guillemot, (*Uria troile.*)
White-winged Guillemot, (*U. grylle.*)
Great Northern Diver, (*Colymbus glacialis.*) Common; resident.
*Red-throated Diver, (*C. septentrionalis.*) Very rare.
Red-necked Grebe, (*Podiceps rubricollis.*) Common in winter.
Pied-billed Grebe, (*P. Carolinensis.*) Very rare here.
*Cormorant, (*Phalacrocorax carbo.*)
*Wandering Shearwater, (*Puffinus cinereus.*)
American Oyster-catcher, (*Hœmatopus palliatus.*) Has been seen here, (doubtful I think, J. R. W.)

LIST OF BIRDS OF BERMUDA.

BY LIEUT. BLAND, R. E.

COMMUNICATED BY JOHN R. WILLIS.

NOTE.—The systematic names in the following list, with the exception of Nos. 26, 29, 51, 73, and 94, are taken from Audubon's Synopsis of the Birds of North America, published in 1839.

1. *Pandion haliætus*—Osprey, Fish Hawk, or Fishing Eagle.
2. *Falco peregrinus*—Peregrine Falcon, or Duck Hawk.
3. *Falco columbarius*—Pigeon Hawk.

4. *Circus cyaneus*—Common Harrier.
5. *Surnia nyctea*—Snowy Owl.
6. *Ulula acadica*—Acadian Night Owl, or Little Owl.
7. *Otus vulgaris*—Long-eared Owl.
8. *Otus brachyotus*—Short-eared Owl.
9. *Corvus americanus*—American Crow.
10. *Lanius ludovicianus*—Loggerhead Shrike.
11. *Chordeiles virginianus*—Virginian Night Hawk.
12. *Chœtura pelasgia*—American Spine Tail, or Swift.
13. *Hirundo purpurea*—Purple Martin.
14. *Hirundo bicolor*—White-bellied Swallow.
15. *Hirundo rustica*—Chimney or Barn Swallow.
16. *Hirundo riparia*—Bank Swallow.
17. *Muscicapa tyrannus*—Tyrant Flycatcher, or King Bird.
18. *Myiodioctes mitratus*—Hooded Flycatcher.
19. *Sylvicola coronata*—Yellow-crowned Wood Warbler.
20. *Sylvicola pinus*—Pine-creeping Wood Warbler.
21. *Sylvicola petechia*—Yellow Red Poll Wood Warbler.
22. *Sylvicola americana*—Blue Yellow-backed Wood Warbler.
23. *Sylvicola discolor*—Prairie Wood Warbler.
24. *Mniotilta varia*—Black and White Creeping Warbler.
25. *Sialia wilsonii*—Common Blue Bird.
26. *Saxicola œnanthe*—Wheatear, (of Yarrell.)
27. *Orpheus carolinensis*—Black-capped Mocking Bird, or Cat Bird.
28. *Turdus mustelinus*—Wood Thrush.
29. *Turdus solitarius*—Olive-backed Thrush.
30. *Seiurus noveboracensis*—Aquatic Wood Wagtail.
31. *Anthus ludovicianus*—American Pipit.
32 *Alauda alpestris*—Shore Lark, or Horned Lark.
33. *Plectrophanes nivalis*—Snow Bunting.
34. *Emberiza graminea*—Grass or Baywinged Bunting.
35. *Ammodramus palustris*—Swamp Sparrow.
36. *Dolichonyx oryzivora*—Wandering Rice Bird.
37. *Linaria minor*—Lesser Red Poll Linnet.
38. *Pitylus cardinalis*—Cardinal Grossbeak, Red Bird, or Virginian Nightingale.
39. *Coccoborus ludovicianus*—Rose-breasted Song Grossbeak.
40. *Vireo noveboracensis*—White-eyed Greenlet.
41. *Bombycilla carolinensis*—Cedar Waxwing.
42. *Alcedo alcyon*—Belted Kingfisher.
43. *Picus varius*—Yellow-bellied Woodpecker.
44. *Coccyzus americanus*—Yellow-billed American Cuckoo.
45. *Columba passerina*—Ground Dove.
46. *Ortyx virginiana*—Common American Partridge or Quail.
47. *Gallinula martinica*—Purple Gallinule.
48. *Gallinula chloropus*—Common Gallinule.
49. *Fulica americana*—American Coot or Mudhen.
50. *Ortygometra carolinus*—Carolina Crake Gallinule.
51. *Crex pratensis*—Land Rail, or Corn Crake (of Yarrell.)
52. *Ortygometra noveboracensis*—Yellow-breasted Rail.
53. *Ortygometra jamaicensis*—Least Crake Gallinule.

54. *Charadrius helveticus*—Black-bellied Plover.
55. *Charadrius marmoratus*—American Golden Plover.
56. *Charadrius vociferus*—Kildeer Plover.
57. *Charadrius semipalmatus*—American Ring Plover.
58. *Charadrius melodus*—Piping Plover.
59. *Strepsilas interpres*—Turnstone.
60. *Tringa pectoralis*—Pectoral Sandpiper.
61. *Tringa himantopus*—Long-legged Sandpiper.
62. *Tringa schinzii*—Schinz's Sandpiper.
63. *Tringa semipalmata*—Semi-palmated Sandpiper.
64. *Tringa pusilla*—Little Sandpiper.
65. *Tringa arenaria*—Sanderling Sandpiper.
66. *Lobipes hyperboreus*—Hypoborean Lobefoot, or Phalarope.
67. *Totanus macularius*—Spotted Sandpiper.
68. *Totanus solitarius*—Solitary Sandpiper.
69. *Totanus flavipes*—Yellow Shanks Tattler.
70. *Totanus vociferus*—Greater Yellow Shanks Tattler.
71. *Totanus semipalmatus*—Willet or Stone Curlew.
72. *Scolopax wilsonii*—Common American Snipe.
73. *Scolopax gallinago*—Common European Snipe.
74. *Scolopax noveboracensis*—Red-breasted Snipe.
75. *Microptera americana*—American Woodcock.
76. *Numenius hudsonicus*—Hudsonian Curlew.
77. *Numenius borealis*—Esquimaux Curlew.
78. *Ardea nycticorax*—Black-crowned Night Heron, or qua Bird.
79. *Ardea violacea*—Yellow-crowned Night Heron.
80. *Ardea lentiginosa*—American Bittern.
81. *Ardea exilis*—Least Bittern.
82. *Ardea virescens*—Green Heron.
83. *Ardea herodias*—Great Blue Heron.
84. *Ardea egretta*—Great American White Egret.
85. *Ardea cœrulea*—Blue Heron.
86. *Ardea candidissima*—Snowy Heron.
87. *Anser hyperboreus*—Snow Goose.
88. *Anas obscura*—Dusky Duck.
89. *Anas acuta*—Pintail Duck.
90. *Anas sponsa*—Wood Duck.
91. *Anas carolinensis*—American Green-winged Teal.
92. *Anas discors*—Blue-winged Teal.
93. *Anas clypeata*—Shoveller Duck.
94. *Fuligula marila*—Scaup Duck (of Europe and America.)
95. *Fuligula perspicillata*—Surf Duck.
96. *Fuligula albeola*—Buffle-headed Duck.
97. *Mergus cucullatus*—Hooded Merganser.
98. *Phalacrocorax dilophus*—Double-breasted Cormorant.
99. *Tachypetes aquilus*—Frigate or Man-of-War Bird.
100. *Sula fusca*—Booby Gannet.
101. *Phæton æthereus*—Tropic Bird (Boatswain or Long Tail.)
102. *Sterna fuliginosa*—Sooty Tern.
103. *Sterna hirundo*—Common Tern.
104. *Sterna dougallii*—Roseate Tern.

105. *Larus sabinii*—Fork-tailed Gull.
106. *Larus bonapartii*—Bonaparte's Gull.
107. *Larus tridactylus*—Kittiwake Gull.
108. *Larus zonorhynchus*—Ring-billed or common American Gull.
109. *Larus occidentalis*—Western Gull.
110. *Larus argentatus*—Herring or Silvery Gull.
111. *Puffinus obscurus*—Dusky Shearwater.
112. *Thalassidroma wilsonii*—Wilson's Petrel, or Mother Cary's Chicken.
113. *Podiceps cornutus*—Horned Grebe.
114. *Podiceps carolinensis*—Pied-billed Dobchick.

There is every reason to believe that the following birds have also been observed in the Bermudas, but as specimens of them have not yet been obtained they are considered to be "doubtful."

Falco sparverius—Sparrow Hawk, (of Audubon.)
Surnia funerea—Hawk Owl, (of Audubon.)
Trochilus colubris—Ruby-throated Humming Bird.
Ectopistes migratoria—Passenger Pigeon.
Ectopistes carolinensis—Carolina Long-tailed Dove, (of Audubon.)
Tringa maritima—Purple Sandpiper, (of Audubon.)
Ibis falcinellus—Glossy Ibis, (of Audubon.)
Phœnicopterus ruber—American Flamingo, (of Audubon.)
Anser canadensis—Canada Goose.
Mergus merganser—Goosander.
Pelecanus fuscus—Brown Pelican.
Larus atricilla—Black-headed Gull.

NOTE.—Since this article went to press a small work has been published by J. M. Jones, entitled "The Naturalist in Bermuda," London, Reeves & Turner, 1859, containing valuable information respecting the natural history of Bermuda. A list of birds furnished by Major J. W. Wedderburn, contains the following additions to the catalogue of Lieutenant Bland:

Cathartes aura, Falco sparverius, Astur fuscus, Lanius borealis, Muscicapa dominicensis, Muscicapa virens, Turdus olivaceus, Turdus migratorius, Trichas marilandica, Alauda arvensis, Emberiza savanna, Emberiza henslowi, Pyranga aestiva, Pyranga rubra, Loxia curvirostra, Loxia leucoptera, Trochilus colubris, Ectopistes carolinensis, Himantopus nigricollis, Rallus virginianus, Anas strepera, Anas boschas, Anas americana, Fuligula clangula, Fuligula rufitorques, Fuligula rubida, Fuligula valisneriana, Pelecanus fuscus, Sterna stolida, Puffinus cinereus.

The following additions are made in the same work by J. L. Hurdis, esq.:

Haliaetus leucocephalus, Syrnium nebulosum, Carduelis tristis, Larus marinus, Mergulus alle, making an addition of 35 species.—Total 149.

Nearly all the species in the list are essentially those of the North American continent, none being peculiar to the West Indies. The following are European species: *Saxicola oenanthe, Alauda arvensis, Crex pratensis, Scolopax gallinago.* Of these the first and third have been taken in the United States, where the others will probably yet be found.—SECRETARY SMITHSONIAN INSTITUTION.

REPORT

ON

ATMOSPHERIC ELECTRICITY.

BY M. F. DUPREZ.

Translated for the Smithsonian Institution from the Memoirs of the Royal Academy of Brussels, by Dr. L. D. GALE.

[This article is, perhaps, the best digest of the history of the observations and researches relative to the electricity of the atmosphere which has ever been compiled, and therefore forms a proper addition to the reports of Müller on other parts of the general subject of electricity which have been given in the appendix to the annual reports of the Regents of the Smithsonian Institution.]

MEMOIR ON THE ELECTRICITY OF THE AIR.

PART I.

THE MEANS USED TO JUDGE OF THE ELECTRICAL PHENOMENA WHICH TAKE PLACE IN THE ATMOSPHERE.

On the construction of the first electrical machine the observers were struck with the resemblance between the effects of electricity and those of lightning; scarcely had the first electric spark been perceived when Wall, Gilbert, and Grey compared its light to that of lightning. This resemblance was still more clearly marked when the discovery of the Leyden phial enabled philosophers to produce with electricity the most astonishing effects of lightning. To render the identity perfect, nothing remained but to collect the electricity which was supposed to exist in the atmosphere. Two methods have been employed for this purpose, one consisting of stationary apparatus, the other of movable ones. In the former case, upright insulated rods or metallic wires, also insulated and stretched in the air, have been used; in the latter, kites, portable electrometers and rheometers are employed. These different articles of apparatus serve to collect the electricity of the air in clear and cloudy weather, during fogs, rain, snow, and hail, and finally in storms.

CHAPTER I.

OF ELECTRO-ATMOSPHERIC APPARATUS.

§ 1. *Of stationary apparatus.*—Stationary apparatus was especially used in the earlier periods when atmospheric electricity engaged the attention. To Franklin* we are indebted for the first idea, and to Dalibard,† a French physicist for the first verification, by experiment,

* Experiments and Observations on Electricity, made at Philadelphia, p. 66; London, 1769.
† Id., p. 106.

of what the former had conceived. His apparatus, established at Marly-la-ville, consisted of a pointed rod of iron forty feet high, the bottom part of which was insulated and fastened on the top of a cottage. On the 10th of May, 1752, between two and three o'clock in the afternoon, a thunder cloud having passed over the rod, it gave out sparks, and exhibited all the other signs of an electrified conductor.

Many philosophers have experimented by means of similar apparatus; some of them have insulated at greater or less heights, and in a horizontal direction or inclining to the horizon, metallic wires, sometimes of considerable length. To obtain strong sparks, Delor* connected several insulated rods of iron with a conductor which he had raised on his house. Le Monnier† fixed on the extremity of a pole, placed in the open air, a glass tube surmounted by a tin pipe ending in a point, to which was fitted a slender iron wire about 300 feet long, which, being insulated, was attached by its other end to a silk cord stretched under a tent. In connecting this wire with several metallic insulated pipes he obtained, with atmospheric electricity, effects not less intense than those which are produced by the best electrical machines. The chief difficulty of this apparatus consisted in insulating properly the conductor designed to collect the electricity, and transmitting it without sensible loss to the instrument which is to indicate its nature and intensity. Canton‡ suggested insulated supports, protected from the rain by covering them with a metallic cap. Read§ effected a more perfect insulation by placing these within an apartment. His apparatus was composed of a pole of fir-wood of about thirty feet long, firmly fixed on a glass supporter covered with gum-lac varnish, and resting on the floor of a chamber situated in the highest story of a house. This pole passed into a hollow cylinder of wood, which, going through the ceiling and the roof, was fastened to the latter. To prevent the rain from falling into the chamber he attached a large tin funnel to the pole, a little distance above the upper part of the hollow cylinder. Copper wires, of one to two millimeters diameter, wound around the pole, were used to conduct the electricity into the interior of the chamber; there they were united in a single wire ending in a metallic ball of two inches in diameter.

A more perfect insulation requires the presence of a conductor designed to establish a connexion between the apparatus and the ground in stormy weather and whenever the electricity is of great intensity. Neglecting this precaution, Richman, professor of natural philosophy at St. Petersburg, was struck by a discharge from an insulated rod which he had set up on his house, and was found dead by the side of his apparatus. To prevent this catastrophe, Read placed at an inch and a half from the knob or ball of his apparatus a bell attached to a metal wire in contact with the ground, and suspended a little metallic ball by a thread of silk between the bell and the knob. This electric chime was designed to warn the observer to be on his guard.

§ 2. *Of the electric kite.*—Another electro-atmospheric apparatus, which the earlier observers also frequently used, is the kite The first

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* Histoire de Electricité, traduite de l'Anglais de J. Priestley; tom. II, p. 164; Paris, 1771.

† Memoires de l'Academie des Sciences de Paris pour 1752; p. 233.

‡ Transact. Philosophiques pour 1752, p. 568.

§ Id., pour 1792; p. 225.

experiment was made by Franklin,* in June, 1752, by uniting two sticks in the form of a cross, to which he fastened the four corners of a silk handkerchief. This kite, surmounted by a pointed iron wire, was held by a hempen cord terminating in a thread of silk, and a key attached between the cord and the silk thread served for a conductor, by which the electricity, descending along the cord, might be drawn off.

This experiment was repeated in France, in a more perfect manner, by De Romas,† of Nerac, who furnished the cord of a paper kite, seven feet high by three broad, with very fine metallic wire, in order to render it a better conductor of electricity. Moreover, instead of drawing forth the sparks with his finger, which might expose the observer himself to the discharge, he made use of a receiver connected with the ground by a chain. Having taken all the precautions which an enlightened prudence could suggest, De Romas ventured to launch forth this apparatus, thus improved, into the most stormy clouds; and in one of his experiments, during a storm attended with little rain or visible lightning, he, for hours, continued to receive flashes or sparks of electricity ten feet long. "Imagine to yourself," he wrote to the Abbe Nollet,‡ "flashes of fire nine or ten feet long, and an inch in diameter, with a report as loud as that of a pistol. In less than an hour I had certainly thirty of these flashes, and thousands of lesser ones. But what gave me the greatest pleasure in this new spectacle was that these great discharges were spontaneous, and that, in spite of the abundance of the electric fluid of which they were composed, they constantly fell on the nearest conducting body. This uniformity of result gave me so much confidence, that I ventured to draw the fluid with my discharger, even at the time that the storm was quite violent; and although the glass arms of this instrument were only two feet long I conducted where I wished, without feeling the slightest agitation in my hand, streams of fire which were seven or eight inches in length."

These details show us how great is the danger which attend experiments of this kind. The scientist Charles,§ in order to avoid touching the cord of the kite in letting it off, rolled it around a cylinder, which he turned by an insulated crank. The cylinder itself was mounted on four pillars of glass. While he wound the cord he established a communication between the cylinder and the ground by means of a chain which terminated in large iron pickets buried in the moist earth; and when the apparatus was insulated he took care to keep himself at a greater distance than these pickets, or in general the nearer conducting bodies, so that if a discharge should happen it might be attracted to them. To attain the same object De Romas‖ constructed an apparatus known by the name of the electric chariot, by means of which he could let off the cord of his kite without running any risk, even when the storm was the most violent.

Among the observers who experimented on atmospheric electricity

* Experiments and Observations on Electricity, p. 111.
† Memoires des Savants Etrang., tom. II, p. 394, 1755.
‡ Memoires des Savants Etrang., tom. IV, p. 514, 1763.
§ Traité de Ph. Experim. et Mathèm., par Biot, tom. II. p. 446. Paris, 1816.
‖ Diction. de Physique, par Brisson, tom. II, p. 174. Paris, 1800.

in this way we should especially mention Cavallo.* After many trials this philosopher found the ordinary kites with which children amuse themselves as useful as those which had been carefully made by himself, provided he took the precaution to cover them with varnish, or saturate them with boiled linseed oil, in order to protect them from the rain. Those which he used in his numerous experiments were four feet long by two broad. Kites of these dimensions appeared to him the best, because they could be managed with ease, and are sufficiently large to sustain the weight of the cord at a convenient height. Those made of cloth or taffeta he found less useful, because they needed more wind to raise them. He discovered, also, that the best cord was formed of two strands of hemp twisted with a copper wire.† Lastly, he tried further to increase the conducting power of the cord by coating it with lamp black, charcoal powder, powdered emery, or other similar substances diffused in gum water; but the effect was scarcely perceptible and of slight duration, because these substances, not sticking to the cord, were easily rubbed off. In this respect Nairne obtained a greater effect by simply steeping the cord in water saturated with salt. In this way it became a very good conductor of electricity, on account of the diffused humidity of the air, which was strongly attracted by the salt.

§ 3. *Of electroscopes, electrometers, and rheometers.*‡—To ascertain the presence of electricity in the rods which they had raised in the air, observers at first drew the sparks with the finger, or with some other conducting body. When the electric tension was too feeble to give out a spark, they placed near the rods a little saw-dust, or some very fine down or cotton, and then observed the attraction which was exercised on these substances. The Abbe Mazeas§ attempted by this method to measure the intensity of atmospheric electricity from the relative distances at which this attraction was manifested. These rude and inconvenient means induced philosophers to have recourse to other more delicate ones, especially when it became necessary to observe electricity of feeble tension, with which the electro-atmospheric apparatus is charged in clear weather. As early as 1752, Nollet,‖ to attain this object, employed his electrometer composed of two simple threads, which were separated from each other by the effect of repulsion when the conductor with which they were connected was electrified. He was the first who reduced the measure of the intensity of atmospheric electricity to the observation of an angle. A little after this Canton,¶ in his experiments, terminated the two threads of the French philosopher's electrometer by little balls of the pith of elder, very nearly the same time that Franklin** used with advantage in the electric chime to study the electricity of the clouds.

* Traité complet. d'Electricité, par Tibère Cavallo, p. 274, et suiv. Paris, 1785.

† Charles used a metallic cord of wire, and M. Peltier a simple wire of (copper?) of 0 *mm.* .5 diameter —(See the Traité de Physique Experimentale et Mathématique of M. Biot, tom. II, p. 444, and the work of M. Peltier entitled "Observations et Recherches Expérimentales sur les Trombes," *introduction*, p. 7. Paris, 1840.)

‡ The term rheometer is used in this article to denote a needle galvanometer.—*Tr.*

§ Hist. de Electricité, par Priestley, tom. II, p. 222.

‖ Lettres sur l'Electricité, tom. I, p. 175. Paris, 1753.

¶ Transact. Philos. for 1753, 1st part, p. 356, 1753.

** Experiments and Observations on Electricity, p. 112.

Various methods were used by the early philosophers to ascertain the nature of the electricity with which their apparatus was charged. Franklin* at first made use of two Leyden phials, one of which was charged with the electricity of the rod, and the other with that of the electrical machine. He placed them on a table at three or four inches apart, and watched the motions of a little ball of cork suspended between the two knobs. If, for example, the two bottles had each of them been positively charged, the ball attracted at first and then repelled by the one was equally repelled by the other; if, on the contrary, the charges were of a different kind, the little cork ball was alternately attracted and repelled by both, and thus performed a series of oscillations between the two knobs. To discover the nature of the electricity with which the electrical chime of bells was charged, he brought a glass tube positively electrified near the edge of the bell which communicated with the rod; in case this had negative electricity the ringing was stopped; if it was positive it continued and even became more lively. Sometimes he suspended a little ball of cork near the edge of the same bell, and by presenting to it a glass tube charged with electricity, he determined the kind of electricity which the bell had communicated. Other scientists had recourse to the various appearances which the electric light exhibited, according as it was produced by positive or negative electricity. For this purpose Le Roy† placed opposite to each other, in a little box having a narrow opening, two small metallic conductors, insulated and each having a blunt point, one of which was connected with the atmospheric apparatus and the other with the ground. In cases in which the atmospheric charged the rod in a perceptible manner, the electricity was conducted by a metallic wire into the inside of the box, and on looking in through a small window two lights could be seen at the ends of the two points. If the point connected with the rod presented a tuft or plume, and the other a luminous star, the observer concluded that the air or cloud was positively electrified; if, on the contrary, the former presented a luminous star and the latter a plume, he inferred that the electricity of the atmosphere was negative. This method was also used by Beccaria‡

In his numerous experiments on this subject Cavallo§ made use of an electrometer, with a graduated dial to measure the intensity of the electricity. He wished to determine the proportion between the intensity and the corresponding divergence of the instrument. For this purpose he gradually brought a tin plate, on which was placed a small quantity of bran, near to a conductor connected with an electrometer, and at the same time to the string of a kite in full flight. He found that when the pendulum of the electrometer stopped at six degrees the conductor began to attract the particles of bran, at the distance of three-fifths of an inch; and when the pendulum was at twenty degrees the attraction took place at an inch and a quarter; and, finally

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* Experiments and Observations on Electricity, pp. 113, 115.
† Journ. de Phys., année 1774, p. 1.
‡ Lettere dell' Electricismo, p. 107. Bologna, 1758.
§ Traité complet d'Electricité, p. 277.

that when it reached as high as thirty degrees it was manifest at two and one-fifth inches.

When the same physicist tried experiments with the kite during the night, and when it was not in his power to recognize at once the nature of the electricity, he charged a Leyden phial, which was so constructed as to preserve its charge for hours. To effect this he placed, by means of a wire, the inside lining in contact with the bottom of a tube of glass sealed into the neck of the phial, while the rod terminating in the knob was inserted into a second glass tube of a narrower bore than the former one, but double its length, and cemented in such a way that it passed in a very slight degree beyond the lowest extremity of the tube. By taking hold of this latter piece in the middle, it could be put within the tube of the phial and made to touch with the rod or stem, the metallic wire in contact with the lining; it could then be drawn out and the bottle lose no perceptible part of its charge. Cavallo* assures us that he kept these phials charged for six weeks. In other cases he fastened to the end of a fishing rod a glass tube covered with gum-lac, at the end of which was fixed a ball of cork, holding suspended by threads two small balls of elder pith. He attached to this ball, by a moveable pin, one end of a conducting wire, and taking the other end in his hand, he raised the fishing rod outside of a window of the upper story of the house. After having held it in this position for some time he detached the wire by a jerk which, pulling out the pin from the ball, left it insulated and charged with an electricity contrary to that of the air, the nature of which was determined by drawing in the apparatus.

In 1783 Archard,† of Berlin, proposed a new electro-atmospheric apparatus; but, notwithstanding all the care he took in its construction, it did not appear that this apparatus exhibited a much higher degree of delicacy than that of the instruments we have already mentioned. It is principally to the perfecting of the instruments by two illustrious philosophers, De Saussure and Volta, that electric meteorology is indebted for a great number of important observations. The first electrometer was made as early as 1749. It was constructed by two members of the Academy of Sciences of Paris, D'Arcy and Le Roy;‡ but its want of sensibility to the electric influence prevented its adoption. We have seen above, that three years later Nollet proposed an electrometer, at once very simple and delicate, and that he used it in his researches on atmospheric electricity. In 1780 Cavallo§ substituted for the two single threads of Nollet two delicate metallic wires, bearing on their ends little balls of the pith of elder. In 1784 De Saussure‖ obtained one of Cavallo's electrometers, and so improved it as to form an instrument superior in delicacy to all that had been used before in the observation of the electrical phenomena of the air. The electrometer of this philosopher was composed of two very fine silver wires, each of them terminated by a little ball of the

* Traité complet d'Electric., page 276, 295.
† Nouv. Mém. de l'Acad. de Berlin pour 1780, page 19.
‡ Mém. de Acad. des Sc. for 1749, page 63.
§ Transact. Philos. for 1780, vol. LXX, page 21.
‖ Voyage dans les Alpes, tom. II, sec. 784, page 194. Neuchâtel, 1786.

pith of elder, half a line or more in diameter, and fitted by little rings to a small metallic stem, which was attached to the upper part of a glass bell two or three inches in diameter. The divisions marked on the bell served to ascertain the number of lines and fractions of lines by which the two little pendulums diverged from each other. Four small slips of tin foil, pasted on the inner surface of the bell, and connected with the metallic base of the instrument, served to carry off the electricity with which the internal air became insensibly charged. In order to determine the proportion which subsisted between each divergence of the balls and the strength of the charge of his electrometer, De Saussure* took two of these instruments, as like each other as possible, and after having electrified one of them so as to of exhibit a divergence of six lines, he touched the rod or stem with that the second; at the instant, the electricity dividing itself equally between the two instruments, the divergence in each of them was four lines. From this it follows that a diminution of one-half in the intensity of the electricity reduced the divergence but one-third. Restoring the second electrometer to its natural state, and placing it anew in contact with the first, the divergence was 2.8; after a third contact, not more than 1.9 lines. He thus succeeded in arranging the elements of a table which changes with different instruments and which every observer ought carefully to construct for himself before he commences a regular series of observations.

To collect electricity De Saussure† made use, in his first experiments, of a fine silver wire, from 50 to 60 feet long; to one end of which was fastened a ball of lead three or four ounces in weight, and its other end was attached to a hook substituted for the ball on the stem of the electrometer, so that it might be detached by the slightest effort. Holding the instrument in his left hand, he cast into the air with his right the leaden ball, which by this movement carried up the conducting wire and transmitted to the electrometer the electricity which it acquired at its greatest height. But by the continuation of the same movement, the wire drew on the hook, loosened it, and left the electrometer charged with the electricity which it had acquired. De Saussure foresaw an objection which might be made to this method of observing atmospheric electricity. "Might not the electricity," said he, "which the ball exhibits be produced by its friction with the air, even though the air may not be charged with electricity? To decide this question by experiment, I attached the same ball to a cord of silk, and I caused it to turn very quickly in the air; but it did not by this contract any electricity, which proves that the friction with the air is not capable of electrifying it, and that thus the electricity which is obtained by my method really belongs to the air into which the ball is thrown."

This method has also been used by Messrs. Becquerels and Breschet,‡ to approximate to an estimate of the intensity of the electricity of the atmosphere at different heights above the ground, except they used an arrow instead of a ball. Having ascended one of the plateaus of the

* Voyage dans les Alpes, tom. II, sec. 793, p. 206.
† Voyage dans les Alpes, tom. II, sec. 785, page 197.
‡ Traité d'Electricité et du Magnétisme, par Becquerel, Tom. IV, page 110, Paris, 1836.

Great St. Bernard, they stretched on the earth a piece of taffeta prepared with gum, on which they coiled a silk thread, covered with tinsel, 262 feet long. They placed one of the ends in communication with the stem of a straw electrometer by means of a knot fastened loosely to it; and after having attached the other end to the iron point of an arrow, they shot it upwards by means of a strong bent bow. The arrow as it rose bore away the conducting thread, as in the experiments of De Saussure, and separated it from the stem of the electrometer. Messrs. Becquerel and Breschet observed that the straws of their instrument diverged gradually as the arrow rose, so as at last to strike strongly against the sides of the bell. They also ascertained that the electricity transmitted to the electrometer by the arrow did not proceed from its friction against the air; for they observed that the experiment was unsuccessful when the arrow was shot horizontally at three feet above the ground.

In 1785 De Saussure* added an important improvement to his atmospheric electrometer. Availing himself of the action which points exercise on the electric fluid, he surmounted it with a conductor, terminating in a point, two feet long and composed of three pieces which could be adjusted to each other. The length of two feet appeared to him the most proper, because a longer conductor would render the instrument much more difficult to manage without increasing its delicacy. To the conductor was attached a little umbrella of very thin brass plate, of a conical form, and four inches and a half in diameter, designed to preserve the electrometer from the rain or snow. By this addition the instrument acquired such a delicacy that the two small balls would diverge when a stick of sealing wax that had been electrified was passed rapidly over it, at a distance of fifteen or eighteen inches.

To make his observations De Saussure† chose an open place, free from trees and houses, and there put the plate and conductor of his instrument into communication with the ground; he then elevated the point so as to bring it to the height of the eye. After having noticed to how many lines the divergence of the little balls corresponded, he slowly lowered the electrometer towards the earth, and marked the height of the point of the conductor at the moment when the divergence had entirely ceased, as the distance from the ground at which the atmospheric electricity began to be perceptible. He regarded the electricity as exhibiting itself at the surface of the earth, when the electrometer without a conductor diverged when it was simply placed on the ground. Finally, if on being placed at the height of the eye, and consequently its point two feet higher—that is to say, seven feet—the electrometer exhibited no divergence, he raised it one or two feet higher; but as then he could no longer observe the balls, he touched the bottom of the conductor with the other hand, and then brought down the instrument near the earth to see if it was electrified. If it was so, he concluded that the atmospheric electricity was sensible at eight or nine feet. If it was not so, he marked in his journal 0,

* Voyage dans les Alpes, tom. II, sec. 791, page 203, and sec. 793, page 211.

† Voyage dans les Alpes, tom. II, sec. 798, page 216.

designating by this that there was no electricity in the air, according to his electrometer and the manner in which he used it.

However important might be the improvements made by De Saussure in Cavallo's electrometer, as applied to researches in atmospheric electricity, still that instrument could not render very feeble degrees of electricity perceptible. Volta conceived the idea of putting it in communication with the condenser, and by this method he obtained a perceptible quantity of electricity in cases where all other instruments indicated nothing.* He also made a change in De Saussure's electrometer.† He left off the balls of elder pith, and substituted for the metallic wires two small straws suspended to very movable little metallic rings, by means of which they were fitted to the stem of the instrument in such a manner as to be near each other in a state of rest. These little straws which, when dry, have the advantage of being much lighter than De Saussure's metallic wires, and presenting for equal weights much more surface, were then enclosed in square glass flasks, having on one side of them a scale divided into 0.5 of a line, and designed to measure their divergence. In this manner Volta formed electrometers, which, though differing in respect to their sensibility, had degrees which corresponded in a given ratio for each instrument through the whole extent of the scale. In that which was the most delicate the straws were two inches long by the sixth of a line broad; and in varying their length and diameter, or in lengthening the metallic wires by means of which they were suspended, he obtained a second electrometer, in which a divergence of 0.5 of a line, regarded as a degree, was equal to five degrees of the first. To render these instruments capable of being compared, he united their stems by a conductor, then communicated to them the same quantity of electricity, and noticed the divergences they exhibited at the same moment. Repeating this operation a certain number of times, with different charges, he had all the elements necessary to form a table which allowed him to reduce the degrees of the least sensible electrometer to those of the one which showed the greatest sensibility.

On comparing his electrometer with that fitted with metallic wires and balls, Volta found that in the latter the divergences were not proportional to the charges, as De Saussure had observed, while in the former, when it is perceptible or moderately so, the divergence is regular up to 26°. Still further he noticed that if the straws were equal in length, a perceptible difference in their size caused scarcely any difference in the variations. Thus, with straws of the same length, the sizes of which were one-eighth and one-quarter of a line, he found but one degree of difference in twenty. He also observed that when the straws are less than an inch in length the electrometer exhibits no longer a regular divergence, and finally, that the flask must not be too large, lest the internal air should retain too long the electricity which it takes away from the straws each moment.

* To obtain exact results by means of the condenser, M. Becquerel observes, plates of brass should not be used, for it is impossible to guard ourselves against the electro-chemical effects resulting from the action of the liquids which adhere to the fingers on the metal. Gilded plates of copper, or rather gilded plates of glass, should be substituted.

† Diction. de Gehler, tom. III, p. 665, and Lehrbuch der Meteorologie von L. F. Koemtz, vol. II, pp. 398 and 400 ; Halle, 1832.

In his experiments Volta made use of the conductor with which De Saussure had armed his electrometer, but he placed at the end of the point an ignited body, such as a piece of spunk or of cotton wick prepared with sulphur. By this means he obtained results which were frequently twice as great as those afforded by the apparatus without the use of the ignited body. As to the mode of applying the combustible to the end of the conductor, in order that it might be kept there the necessary time, and not be extinguished by the wind, Volta placed it in the inside of a coil of iron, adjusted to the point of the conductor. He advises also to attach to the same point a little lantern containing a spirit lamp, in case the rain is such as not to allow using simply spunk or tinder or burning sulphur.*

The great divergence which an electrometer presents when the stem is furnished with an ignited body is worthy of observation. M. Pfaff† says that, in the case where he observed no electrical sign with an electrometer of gold leaf exposed to the air, even while using a condenser, the leaves diverged more than an inch as soon as he fitted to the point of the stem a piece of ignited tinder. Let there be placed on an ordinary electroscope a very small spirit lamp, and at five or six feet above it present a stick of resin feebly electrified; instantaneously there will be seen, according to M. Pouillet,‡ a very great divergence of the leaves; and yet the same body with the same electrical charge produces no sign of divergence if it be presented to the electroscope without flame, even at the distance of an inch. It might be objected that the electricity which is observed in Volta's electrometer furnished with an ignited body is not the result of the influence of atmospheric electricity, but that it is produced by the action of the flame or smoke on the point of the conductor. This objection appears well founded, since M. Becquerel,§ in causing flame to act on metallic bodies which communicate with a condenser, observed a disengagement of electricity, the cause of which he attributed to an electro-motive action which existed between the flames and these bodies. To be able to judge how far confidence could be placed in observations made in this manner, Schübler ‖ repeated the same experiments in the open air and in closed rooms. During the burning in the house of three grains of tinder or of sulphur, he could not obtain the slightest sign of electricity with Volta's electrometer; while the same quantity of these substances burned in the open air, at the same hours in the afternoon, when atmospheric electricity is at its *minimum*, was sufficient to charge the electrometer, or even a small Leyden phial, to such a degree that it could be used for other researches in electricity. He could scarcely obtain any signs of electricity by the combustion of a hundred grains of spunk or tinder in closed rooms. It follows, there-

* M. Mattenci, resting on the electric conductibility of the vapor of phosphorus, prepared in metallic tubes sticks of this substance one or two millimetres in diameter, to adapt them then to the point of the conductor destined to receive the atmospheric electricity.—(See Biblioth. Univ. Sc. et Arts, tom. LI, p. 351; Genève, 1832.)

† Diction. de Gehler, tom. VI, p. 518.

‡ Ann. de Chim. et de Phys., tom. XXXV, p. 401, 1827.

§ Ann. de Chim. et de Phys., tom. XXVII, p. 17, 1824.

‖ Journal de Schweigger, tom. XIX, p. 1, 1817.

fore, that if there is a disengagement of electricity by the action of the ignited tinder on the conductor of Volta's electrometer, this electricity is too feeble sensibly to affect the results which are obtained by this instrument in the researches on atmospheric electricity.

But how does an ignited body increase the divergence of the electrometer if the electricity disengaged must not be attributed to an action of the flame on the metal? We do not know what explanation Volta gave to this phenomena, but M. Gay Lussac* says: "The smoke which passes off from the tinder ignited at the point by which the electrometers, designed to ascertain atmospheric electricity, are armed, may exhibit an image of an electrified cloud. This smoke acts as as a conductor, which, as it expands, collects the electricity of the air, and renders it more sensible by accumulating it at the surface; but the ignited tinder acts also in another way by heating the air and thus rendering it a conductor." We shall see farther on that an electrometer becomes charged by induction and not by the contact of the surrounding air; consequently that its straws or leaves may diverge as well negatively as positively in the same stratum of air. We may conclude from this that the smoke produced by the ignited tinder does not act as a conductor to accumulate in the electrometer the electricity of the surrounding air, for then it would be necessary for the instrument to take a permanent and not a transient charge. We believe rather, with M. Gay Lussac, that the effect produced is from the conductibility which the air acquires by heat; for we see that the intensity of the electric tension, observed in the electrometer, depends on the effect of the conductibility of the air, this latter favoring the electric radiation of the instrument.§ Besides, M. Gay Lussac has demonstrated by a very simple experiment that the air, the temperature of which is raised, becomes a conductor of electricity. He observed that an electrometer on being charged quickly loses its electricity when red hot charcoal or the flame of an insulated candle is brought near it, while it preserves its charge if the charcoal has not been heated. Thus may be explained the fact observed by M. Mattencci,† that the discharges of a musket, fired at the height of the flame of electrometer of Volta, occasion a very strong divergence in the straws of that instrument.

By means of series of straw electrometers rendered capable of comparison by the method indicated by Volta, Schübler‡ made numerous observations, the special object of which was to determine the periodical variations of atmospheric electricity. These instruments were provided with metallic stems three feet long, terminating in coils, furnished with a combustible substance; and, like Volta, he took for the unit of his scale 0.5 of a line. Schübler preferred Volta's electrometer to that of Bennet, with gold leaf, because with the former the valuation by degrees could be made with more exactness, because it preserved longer the electricity which had been communicated to it, and also because it is more convenient to observe comparatively the de-

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* Ann. de Ch. et de Phys., tom. VIII, p. 68, 1818.

† Biblioth. Univers. Sc. et Arts, tom. LI, p. 352, 1832.

‡ Journ. de Schweigger, tom. III, p. 123, tom. VIII, p. 22, and tom. XIX, p. 11, 1811, 1813, and 1817.

§ The term radiation is used in this article to denote the escape of electricity from the point of the electrometer by the partial conduction of the air.

grees of increase or diminution which occur in its index. Schübler has also remarked that the electrometer is charged much more quickly when, instead of tinder, there is fixed on the point of the stem a wick prepared with sulphur.

The discovery of electro-magnetism having led to the construction of the rheometer, this instrument was soon applied, in the hands of philosophers, to ascertain the electrical phenomena of the atmosphere. Its first use as an electro-atmospheric apparatus was by M. Calladon.* After having demonstrated, in 1826, that an electrical machine might, like the pile, produce a current capable of deflecting the magnetic needle, this scientest showed that the rheometer might become a means of determining the quality of electricity which passes into the conductors used in the researches on atmospheric electricity. He raised on the observatory of the college of France a pole thirty-six feet long, supporting a conducting wire covered with silk, and terminated by two fine needles diverging a little from each other. This wire passed through a glass tube and descended into a chamber where two rheometers were placed with two needles, one of 100 and the other of 500 coils, the wire of which was doubly covered with silk, and each series of coils separated by taffeta, prepared with gum. He attached the conducting wire to one end of the wire of one of these instruments, while the other end communicated with the ground. By means of this arrangement he obtained deviations of the magnetic needle, not only during storms, but also in days when the sky was merely cloudy. M. Peltier and M. Clarke,† of Dublin, also used this instrument with advantage, especially for studying the distribution of the electricity in thunder clouds. They used a rheometer of 3,000 coils, the wire of which was covered with silk, and also with a coating of gum-lac varnish, which insured the best insulation.

Researches on atmospheric electricity have also been made with other instruments than those we have mentioned. In 1794, Read‡ used for this purpose the electrical condenser, an apparatus described first by Bennet, and afterwards improved by Nicholson. It was designed, by the aid of a movable disk, to render a small portion of electricity perceptible by increasing the quantity of electricity contained in two other similar and opposed stationary disks. From experiments with this instrument Read concluded that the atmosphere when entirely pure is almost always in a state of positive electricity, and that when it is vitiated, whether by putrefaction of vegetable matters or by that of animal substances, its electricity becomes negative; and finally that respiration alone renders the electricity of the air negative. These results, obtained by means of the doubler, have not been confirmed by experiments made with other instruments; on the contrary, it has been discovered that they must be attributed not to atmospheric electricity, but to other causes derived from the imperfections of the instrument. The use of that apparatus, therefore, has been abandoned in all researches on electricity of this character.

In 1809 De Luc exhibited to the Royal Society of London, under the

* Ann. de Chim. et de Phys., tom. XXXIII, p. 62, 1826.

† Comptes Rendus, tom. III, p. 145, 1836; and Philos. Magazine, tom. XVI, p. 224, 1840.

‡ Journ. de Phys., tom. XLV, p. 468, 1794.

name of the electric column and atmospheric electroscope, consisting of a dry pile, composed of 1,600 disks of zinc and gilded paper, which appeared to him adapted to determine the electrical variations of the air and of the surface of the earth. A small pendulum set in motion by the electricity of the column alternately struck against two metallic balls, one in constant communication with the positive pole, the other with the negative pole or with the ground. The vibrations of this pendulum would, according to De Luc, indicate by their frequency the electrical variations of the surrounding medium or those of the surface of the ground.* But it is now known that the irregularity of the vibrations of the pendulum cannot be regarded as an indication of the influence of the surrounding electricity; that it is the character of the dry pile to permit only a very gentle circulation of electricity, and not to become recharged, except very moderately, after having lost its electricity by the communication of its poles; consequently, that more or less time must pass before sufficient electricity is accumulated at the two poles of such a battery to renew and continue the movements of the pendulum. Besides, Schübler† examined this question, and concluded, from a great number of observations, made under very different circumstances, that the action of De Luc's dry pile was subject to the influence of moisture, and not to that of atmospheric electricity.

CHAPTER II.

OF THE USE OF ELECTRO-ATMOSPHERIC APPARATUS.

When we examine the opinions which have been advanced as to the phenomena of atmospheric electricity, we are struck with their want of harmony. The mode of action of this agent on the instruments has been variously interpreted by scientists; and while some consider these instruments as having been electrified by the contact of the surrounding air, whose electricity is positive, others see in the electrical signs which are manifested only the effect of electricity of induction. In speaking of the electrical phenomena of the atmosphere M. Biot‡ says:

"The experiments on atmospheric electricity present the only case of an indefinite medium, such as the air, all the molecules of which are individually charged with an excess of electricity of the same kind adhering to their surface; so that the whole mass of the medium becomes pervaded with it in proportion to the heights. The different particles of this medium cannot be in repose except from the mutual compensation of their repulsive forces, combined with their weight; and the same condition applies to the conducting bodies which are immersed in it. Thus, in all bodies in the air, the electrical equilibrium cannot take place when their natural electricities are merely neu-

* Biblioth. Britann. Sc. et Arts, tom. XLVII, p. 213. 1811.
† Journ. de Schweigger, tom. XV, p. 130.
‡ Traité de Phys. Expérim. et Mathém., tom. II, p. 457.

tralized; it can only take place when they possess an excess of one or the other electricity which is the same as that of the stratum where they are found. If the particles possess a greater excess of this same electricity they will act only in virtue of this excess upon each other and upon all the molecules of the surrounding air; they must then mutually repel each other. If, on the contrary, the excess of electricity which they possess is less than that which they naturally receive in the position where they are placed, the mass of the medium will act on each one of them by virtue of this difference, and their natural electricities will be decomposed as much as is necessary to complete what is wanting to them of the electricity of the medium; by virtue of this addition they repel the medium as much as the medium repels them, and will therefore undergo no more action. But they act on each other with the excess which they have acquired from the opposite electricity, and if the medium is an indefinite fluid composed of particles susceptible of being electrified by contact, this excess will by degrees be dissipated in space."

Experiment does not sustain this mode of regarding the action of the electrified air on the conducting bodies which are immersed in it; for it would follow that an electrometer ought to present almost always a negative divergence at the instant of its exposure to the air under a serene sky, since its leaves would act on each other with the excess of the electricity which they had acquired by the positive influence of the stratum of the surrounding air. It would likewise follow that if, after having freed the instrument of its negative electricity, we should lower it or raise it suddenly the leaves would exhibit a positive divergence in the former case and a new negative divergence in the latter. Now, experiment shows that precisely the contrary takes place. Other phenomena, of which we shall have occasion hereafter to speak, are equally irreconcilable with the principle announced by M. Biot.

In his explanation of the formation of thunder clouds, M. Guy Lussac* supposes that the electricity is diffused in the atmosphere, and that it exists in a free state, ready to be transferred and collected on the conductors which are presented to it. On this supposition the electrometer would always take a quantity of electricity corresponding with that existing in the air into which it is immersed; but this electricity cannot be the cause of the positive divergence which is observed, since the surrounding air and consequently the armatures and the gold leaves of the instrument being then in the same degree of electrical tension, there is no reason why the last acted on by equal forces should diverge from each other. This appears from the following experiment, for which we are indebted to M. Peltier.† This scientist took a glass globe covered with tin-foil, with the exception of two small openings opposite each other so as to see what passed within. At the centre of this globe he placed a small electroscope, the gold leaves of which corresponded to the visual ray, crossing the two openings; he then charged the globe with a considerable quantity of electricity,

* Ann. de Ch. et de Phys., tome VIII, p. 163. 1818.

† Observ. et Recherch. Expérim., sur les Trombes, introduction, p. 3.

without obtaining the slightest divergence in the gold leaves. The effect was the same when he previously charged the electroscope with a quantity of electricity, similar or contrary to that of the globe; the divergence given to the leaves was not in the least changed. The same conclusion may be drawn from an experiment made by Mr. Faraday,* in which he saw no perceptible divergence in an electrometer placed in air, which had been powerfully electrified in a small insulated chamber, the wall of which, composed of conducting substance, communicated with a powerful electrical machine, which was worked in an adjoining room.

De Saussure† was the first to observe that atmospheric electroscopes varied in their indications, according as we raise or lower the instruments; he likewise recognized in these variations all the signs of electricity of induction, and not those of the permanent electricity of contact. M. Erman,‡ of Berlin, in prosecuting these researches with very delicate electroscopes, concluded, from his experiments, that the variations in the nature and intensity of the electricity, manifested by these instruments were entirely independent of the surrounding air, and resulted from the fact that all bodies—even those which are absolutely in electrical equilibrium with the earth and the air, and which cannot consequently produce any divergence, have yet, under the influence of the earth, atmospheres of free electricity of their own which are modified mutually by the changes produced in their removal or approach. M. Peltier§ has recently resumed the enquiry, and, while he has been led to a new interpretation of the electrical phenomena of the atmosphere, he has shown, by decisive experiments, that it is by induction solely and not by the contact of the air that the instruments become electrified. The considerations which he adduces in support of his opinion, and which he communicated to the Academy of Sciences, at the sitting of February 8, 1841, are the following:

1. If the stem of an electrometer is surmouned by a polished ball, and the instrument is brought to an equilibrium by touching the covering plate and the stem at the same time, we may leave it exposed to the agitation of the air under a clear sky for hours, keeping it at the same height, without its exhibiting the least sign of electricity.

2. If the stem ends in a point the electrometer sometimes takes a little electricity after half an hour or more; this time is much shortened if the stem ends in a bundle of metallic points or in an ignited body, as in the experiments of Volta.

3. In case the instrument gives no indication, if we raise it a few feet, the leaves immediately diverge positively; if, on the contrary, it is lowered the same distance below the point of equilibrium, its leaves diverge negatively; and every time that it is brought to the height of equilibrium the leaves fall to zero.

These experiments clearly demonstrate that the electricity exhibited by the electrometer is, in fact, developed by induction; for, if it were otherwise, the air would communicate to this instrument when it is

* Experimental Researches in Electricity, eleventh series, p. 5, 1838.
† Voyage dans les Alpes, tome II. sec. 795, p. 212.
‡ Journ. de Phys., tome LIX, p. 98. 1804.
§ Comptes Rendus, tome XII, p. 307. 1841.

raised or lowered, a permanent and not a transient charge. Further, M. Erman* has remarked that if we cover the stem of a glass tube, closed above, the phenomena remain the same; positive or negative divergence shows itself equally well, according as the direction of the motion is up or down. The same result is still obtained by placing a second tube around the first, in order more effectually to intercept the contact of the air. Finally, to give to this demonstration every possible accuracy, M. Peltier and M. Pfaff† reproduced in a room the same effects as under a clear sky; the former experimenting under an insulated globe suspended to the ceiling, and positively electrified; the latter, by alternately raising and lowering the electrometer in an apartment, in which the upper strata of the air had been strongly electrified by means of points communicating with the electrical machine.

It hence follows that an insulated conductor, which has been exposed to the air under a clear sky, is in the same state as if it had been subjected to a body positively electrified; it has consequently its natural electricity separated, the negative attracted to its upper part, and the positive repelled to its lower part. If, in this state, the lower part is for an instant placed in connection with the ground, the positive electricity escapes and the upper part remains charged with negative electricity; the conductor, as M. Peltier says, is equipoised. But then the lower part cannot receive a new positive charge, inasmuch as a new decomposition of its natural electricities would take place, which may happen either in raising the conductor in the air or in favoring the escape of the electricity attracted. The same extremity becomes charged, on the contrary, with negative electricity, either in lowering the conductor or in modifying the electrical induction to which it is subjected; such is the natural consequence of the facts which we have related above. If the application be made to electro-atmospheric apparatus, we see that all such apparatus show the great inconvenience of indicating the differences of one and the same state, and not of absolute quantities, as in other instruments of meteorology like the thermometer and the barometer; they establish and measure only the changes which occur in their electric state, as they recede from the normal condition, which is that of equilibrium.

From the preceding considerations, it is easy to give a reason for what takes place in the electro-atmospheric apparatus, and to see how their indications may be interpreted. A stationary apparatus may be compared to an insulated conductor which is in equilibrium; it cannot, on account of its immovableness, afford signs of electricity at its lower end, except by the radiation of the electricity which is has previously attracted, an effect which takes place slowly if the air is dry, and rapidly if it is moist or becomes a conductor by any means whatever. This radiation will be promoted also if the apparatus is subjected to the influence of a cloud powerfully electrified, or if it has considerable length; for in this latter case its extent may make up for the weakness of the local radiation produced by the conductibility of

* Journ. de Phys., tom. LIX, p. 100. 1804.
† Dictionn. de Gehler, tome VI, p. 507.

the air. From this it follows that, however decided may be the signs of electricity which stationary apparatus exhibits at the approach of certain clouds and at the beginning of rain, they usually disappear when the sky is clear or more or less free from clouds. This apparatus is then insufficient to study atmospheric electricity in clear weather; it can only show the existence of this electricity. Besides, in the case where the radiation is active, they must frequently furnish uncertain results, because the insulation of their supports, besides the difficulty of rendering it perfect, varies with the hygrometrical state of the air, the dust which settles on them, and a multitude of other secondary causes.

Beccaria, who devised a great many contrivances, avows that frequently he was ignorant whether the absence of the electrical signs proceeded from the fact that the air was deprived of electricity, or because the humidity had destroyed the insulation.

Another cause of error, to which M. Peltier* first called attention, is found in the chemical action which the moisture exercise on the wire or the oxydizable points of the apparatus. This scientist states that among the apparatus which he set up he found one which constantly gave an electrical current, because it was formed of a rod of iron painted with oil. In moist weather the needle of a rheometer was deflected to 80° without there being any electrical action of the atmosphere. It was to avoid this great inconvenience that M. Peltier constructed of platina the parts of his apparatus which must remain exposed to the action of the air. We may also remark that there are multitudes of cases where the use of stationary apparatus must be difficult, as when we attempt to study atmospheric electricity on mountains, in open sea, and generally in places where there are no buildings. Perhaps, then, we might use the apparatus recommended by M. Pfaff,† consisting of a long glass support, sustained by three feet, and bearing a disk of wood, with which is connected, by means of a hinge, a metallic stem composed of several pieces fitted to each other. This apparatus may be placed in the open air in such a way that its stem, movable on its hinge, may take any desired inclination. A simple metallic wire communicating with the stem serves to conduct the electricity to an electrometer.

If the stationary apparatus is not well adapted to ascertain atmospheric electricity in clear weather, it may still be very useful to establish the electrical state of the clouds, especially in stormy weather, provided care be taken to connect it at the same time with a discharging conductor. In these circumstances, M. Peltier‡ made use of a simple insulated copper wire, of about a hundredth of an inch in diameter, which was raised at one of its ends to about eighty feet above the ground, and at the other plunged into a well forty feet deep. This wire, wound with silk and covered with many coats of thick varnish, was terminated above by a tuft of platina wire; and the lower end, which was plunged into the well, was also terminated by a wire of the same metal. Towards the middle of the wire was interposed a rheometer

* Ann. de Ch. et Phys., 3d series, tom. IV, page 414. 1842.
† Dictionn. de Gehler, tom. VI, page 517.
‡ Comptes Rendus, tom. I, page 95, and tom. III, page 145, 1835 and 1836.

of varnished wire, or an electrometer, according to the object. The electricity which descends along this wire being always of the same nature with that of the cloud, we ascertain the character of the one by observing that of the other. It was with a similar apparatus, well insulated and protected as far as possible from the chemical action of moisture, that M. Peltier made numerous and important observations on the electrical phenomena which take place during storms. We might accomplish the same object by the use of the kite, as many observers have done; but, as we have seen, the danger of this movable apparatus in stormy weather is so great that prudence alone ought to forbid its use in this case. Besides, the facts which it furnishes can be obtained, as it appears to me, equally well by the use of stationary apparatus. For in the great number of cases, not to say all, the kite can only be influenced by the lower clouds; we can ascertain nothing respecting the ranges lying above these clouds, or discover what belongs to each one of them, and thus furnish the means necessary to an analysis of the different phenomena which concur in the formation of storms. We believe that an insulated wire, arranged like that which M. Peltier used, and affording all possible security, will accomplish the same object much more conveniently.

But if the use of the kite possesses little advantage in stormy weather, it is not so when we use it in clear weather. It may then render eminent service to science, and it was by means of it that De Romas, Beccaria, Cavallo, and many other observers ascertained the fact that the influence of atmospheric electricity increases in proportion to the distance from the surface of the earth. It furnishes a simple means of determining the law according to which this increase takes place, a law which is not yet known, but which evidently depends on the want of conductibility of the constituent parts of the air, and must consequently vary on account of the vapor which rises from the ground, or which settles on the earth. M. Peltier* has successfully used the kite to accomplish this object. He ascertained the height to which it ascended by employing an insulated drum, around which the metallic wire was coiled, and furnished with an index which constantly showed the length of wire given out. If we would ascertain the height, let the cord be the hypothenuse of a right-angled triangle, of which one of the sides is the perpendicular height of the kite. If we wish to examine atmospheric electricty at very great heights, we may make use of a series of kites of different sizes.† We first allow the largest sized kite to reach its greatest height; then, having attached its string to a second, but of less size, we let it likewise ascend, its string being in its turn connected to a third, and so on. This union of kites was used for the first time by Wilson‡ when engaged in his researches on the temperature of elevated strata of air in 1749. The height to which the first kite thus reached was very remarkable, since it could be frequently seen to

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* Comptes Rendus, tome X, page 712, 1840.

† In his experiments on atmospheric electricity, *Cuthbertson* made use of three kites combined in this manner, and the cords of which presented an entire length of 1,500 feet. Bibliotheque Britannique, Sciences et Arts, tome XXXIX, page 118. Geneva, 1808.

‡ Lehrbuch der Meteorol., by Koemtz, tome II, page 395.

disappear in the clouds. We can in this way examine the state of very high clouds, the electricity of which would be too feeble to act in a sensible manner on apparatus placed at the surface of the earth.

In reference to the great utility of the kite in researches on atmospheric electricity, it is necessary to take into consideration the inconvenience of not being able to use it except during winds. In calm weather we might substitute for it a balloon furnished with the necessary additions, and retained by a cord which is a good conductor of electricity. But this method of experimenting is much less simple, because we can not always procure hydrogen gas, and because the lateral currents bear the balloon to the leeward and prevent its rising perpendicularly. We should also mention certain effects obtained by the use of the kite, and which do not appear to be owing to the influence of atmospheric electricity, but to the induction of an electric current on itself. It is well known that Mr. Henry,* [now Secretary of the Smithsonian Institution,] has shown that a discharge of ordinary electricity produces a powerful secondary current in the wire adjoining; he thinks that ordinary electricity ought to produce an analogous effect in the same wire when the discharge takes place; and gives on this subject the following experiment made on atmospheric electricity, in 1836, by a committee of the Franklin Institute of Pennsylvania: Two kites had been attached and raised with an iron wire in place of cord; the wire extended for the length of about a mile. The weather was perfectly clear, and yet sparks drawn from the wire were of such great pungency that fifteen persons joining their hands, and standing on the ground, received the shock at the same moment that the first touched the wire. On holding a leyden phial by its external coating, and presenting the knob to the wire, a very strong shock was received which was nothing but the result of an action of sudden and powerful induction. According to Mr. Henry, these effects must not be attributed to the electricity accumulated at the ends of the wire, for it was necessary to approach the finger to about one-fifth of an inch before receiving the spark; he adds that we cannot attribute them to quantity only, since Wilson's experiments have proved we cannot produce the same effect with an equal amount of electricity diffused over the surface of a great conductor; he concluded, therefore, that the effect observed was owing to an induction of the current on itself. The wire containing a considerable quantity of electricity of feeble tension, which passed in the form of a current, it produced an induction at the end of the discharge, as in the case in which a long wire transmits a voltaic current. To the same cause must be attributed the remarkably pungency of the sparks, though very small, which are received from a long conductor along which a feeble current of ordinary electricity passes.

The electro-atmospheric apparatus acquires great sensibility when the insulated conductor is movable. De Saussure† states that he obtained signs of electricity when he raised his electrometer, furnished

* Contributions to Electricity and Magnetism, page 47.—From the Transactions of the American Philosophical Society, vol. VI.

† Voyages dans les Alpes, tom. II, § 799, p. 218.

with a point, only from four to seven feet above the ground, at the time when stationary conductors of more than a hundred feet high gave no indication. What we have given above furnishes a sufficient explanation of this fact; for the movable apparatus being under the influence of an electricity which acts on them by induction, the electrical equilibrium must be disturbed at every change of elevation. Besides this, the stationary apparatus, as we have seen, however carefully constructed, loses in part its isolation when the air is moist, during fogs, heavy dews, cold and rainy nights; while a movable apparatus, such as an electrometer furnished with a point, which we usually keep in the house, and which is not exposed to the air except at the moment when we wish to use it, always has a sufficiently good insulation. This kind of apparatus is the only one which has yet led to any definite results in regular observations, made under a clear sky, at the surface of the earth.

There are two ways of using the electrometer, affording different indications, and which we should be careful not to confound. If we desire only to know the nature of the electrical influence, whether under a clear sky or a cloudy one, let the conducting stem be terminated by one or several points, or by an ignited body; the leaves, after having been brought to an equilibrium, will slowly or rapidly diverge by the repelling electricity without the necessity of moving the instrument. But the electricity thus collected being wholly dependent on the conductibility of the air, and consequently varying with the moisture in that medium, the rain and even with the force of the wind, this mode of experimenting will simply give the measure of the repulsive electricity which the instrument is in a state to preserve in consequence of its insulation, and not that of the electric induction to which it is subjected. To obtain this latter, M. Peltier* directs that the conducting stem be terminated by a ball, which, at the same time that it prevents the radiation of the electricity accumulated at the lower extremity, increases the effect of the induction. It is clear that, after having brought the instrument to an equilibrium at a certain height, the indications which it will give by its elevation or its depression will depend only on the induction of the atmospheric electricity, and may consequently be used as a measure of it. This method is that which M. Peltier used in his regular observations, and it appears to be the only one suitable to ascertain the variety of the electrical tensions at short intervals of time. When this scientist wished to make an observation he ascended on a terrace and placed his electrometer on a tablet raised about five feet; he brought it then to an equilibrium by touching the stem and the lower part with a metallic wire; then he descended into a room below the terrace, and there placed the instrument charged with electricity opposite to that of the atmosphere on a tablet designed for it, where he afterwards read it. This series of operations could be made with such rapidity that it required only eight seconds.

M. Peltier remarked that for these experiments he needed only to use a ball of about three inches in diameter, and not a longer stem

* Annales de Chimie et de Physique, 3d series, tom. IV, p. 400, et suiv.

of the electrometer than twenty inches; he preferred even one of from twelve to sixteen inches. A longer rod diminished the sensibility of the instrument, because the electricity driven to the upper extremity leaves to the opposite electricity the remainder of the length over which it is to be distributed. Consequently the longer the stem the less is the electricity which reaches the gold leaves.

Instead of raising the instrument, he prefers to lower it below the point of equilibrium, because it is not convenient, and frequently it is even impossible to read exactly the number of degrees which the apparatus indicates while the air is charged with resinous vapors, when it is necessary to raise it one or two metres above the same point. M. Peltier remarked, however, that the divergence of the leaves or the deviation of the needle of his electrometer is less on lowering the instrument than on raising it; so that we ought to fix the proportion in order to establish the direct tension in the formation of the tables which it may be desirable to prepare. The reading was made in a room, and not in the open air, to avoid the inconveniences of the wind, rain, the heat of the sun, and especially the error which may result from the electric tension which the head of the observer receives in the open air, and which might act on the instrument and complicate its indications. Finally, to avoid alike the induction of the hand on the stem, this is touched in the lowest part with a fine metallic wire.

Besides electrometers, science also has rheometers to measure the intensity of atmospheric electricity; but, as M. Peltier* remarks, two things limit the use that can be made of them. First, a great quantity of electricity in motion is necessary to produce deviation in a rheometer, while a small portion is sufficient to determine the divergence of the gold leaves of an electrometer. M. Peltier† proved that the escape of a quantity of electricity, represented by a deviation of 7.069 degrees of his static electrometer, was needed to produce a single degree of deviation in an excellent rheometer of 3,000 coils of a wire of 0.15 millimetres, having a system of light needles of five centimetres in length. Then, also, it was necessary for the deviation of this instrument to apply a continued current, and not a succession of small discharges. It therefore follows that the rheometer gives no indication during the dryest and most electric days, if the extremity of the wire is not raised to a great height in the air, while in the last case the electrometer exhibits a very powerful electricity. Thus it is that M. Peltier observed in his experiments under a clear sky, that the deviation of his rheometer did not begin to be produced till the kite with which one of the ends of the wire of the instrument was connected had reached the height of one hundred feet above the ground, while his electrometer indicated an increasing positive electricity beginning from the height of ten feet.

If the rheometer gives no indication under a clear sky, when the extremity of the wire is placed at a small height above the ground, it is not so when clouds and especially thunder gusts pass over the

* Comptes Rendus, tom. X, p. 712. 1840.

† Annales de Chimie et de Physique, tom. LXVII, p. 440. 1838.

apparatus. In this case the radiation from the wire raised into the atmosphere may become so considerable that the needle moves rapidly and even reaches its *maximum* of deviation.

We shall finish this first part of the general subject by a succinct summary of what we have said of the use of electro-atmospheric apparatus:

1. The electro-atmospheric apparatus becomes electrified by induction and not by contact of the air. It acts in the same way as if it were placed under a body positively electrified; consequently, it does not indicate the absolute quantities, but the differences of one and the same state.

2. Stationary apparatus, on account of their immobility, must be considered as conductors in equilibrium; they are insufficient for the study of atmospheric electricity under a clear sky and in a dry time; they do not become electrified, except by their radiation, and even then they do not indicate the nature of the electricity, except when their insulation is perfect, and they are not influenced by electric currents proceeding from the chemical action of the steam upon the oxydizable parts which enter into their composition.

3. Stationary apparatus in which the two conditions mentioned just above are fulfilled is very well suited to observe the sudden or gradual changes which take place in atmospheric electricity, during storms, and in general under the influence of clouds sufficiently electrified. An insulated copper wire, covered with silk thickly varnished, terminated at the end in platina, and arranged in the manner indicated by M. Peltier, appears to be best suited to this case.

4. Prudence alone should prevent the use of kites in stormy weather. When the sky is more or less clear, this movable apparatus may serve to study the variations which occur in the induction of atmospheric electricity, when the kite is raised from the surface of the earth towards the upper regions of the atmosphere.

5. We may obtain under a clear sky remarkable effects, such as very powerful shocks, by means of the kite, which, according to Mr. Henry, we must attribute not to the direct influence of atmospheric electricity, but to the phenomena of induction of an electric current on itself.

6. When it is desired by a series of observations to measure the variations of atmospheric electricity, and obtain comparative results, the electrometer furnished with a stem terminated in a ball, appears to be the only suitable instrument. We put it carefully in equilibrium, at a definite height, and then lower or raise it a constant distance. Its indications may then serve to measure the atmospheric electricity.

7. If the stem of the electrometer is terminated by one or several points, or by an ignited body the instrument furnishes indications which are dependent on the conductibility, or in other words on the moisture of the surrounding air.

8. The rheometers are not deflected, except by a continued current of electricity, and their sensibility is far inferior to that of the electrometers. They are very useful in stormy weather and at all times when the influence of atmospheric electricity is very strong.

PART II.

OF THE STATE OF OUR KNOWLEDGE OF THE ELECTRICITY OF THE AIR.

CHAPTER I.

OF THE ORIGIN OF ATMOSPHERIC ELECTRICITY.

In the month of July, 1752, Cassini de Thury * observed that a rod placed on the observatory of Paris became electrified when there was no appearance of a thunder cloud above the horizon; but at this period it was believed that such clouds were necessary to the production of this penomenon, and this led him to suspect that there was a cloud near the horizon, which, without being perceived, communicated to the air electricity enough to charge the insulated conductor. In the meantime the observations made by Le Monnier† soon left no doubt that the electro-atmospheric apparatus does become electric under a clear sky. During a drought of six weeks, from the middle of September to the end of October, 1752, this scientist found that the apparatus which he had established in his garden of St. Germain en Laye, became sensibly electrified, though the clearness of the sky was not disturbed by clouds during all this time. The experiments of Beccaria, Cavallo, and especially those made with the most delicate instruments by De Saussure, Volta, and Schübler, confirm this result. These philosophers took pains to determine the character of atmospheric electricity, and from the sum of their observations we may conclude that in clear weather the atmosphere is always positively electrified.

Many hypotheses have been framed to account for atmospheric electricity. We shall present a brief exposition of some of these and show how far they correspond with the present state of the science.

When friction was the only known agent capable of producing the decomposition of the electric fluids, it was natural to seek the source of atmospheric electricity in the friction of the air against the clouds and the earth and against itself. This opinion was entertained by Nollet ‡ and adopted by many philosophers; but it was afterwards entirely abandoned, when observation taught that there was no relation between the intensity of electricity and the force of the wind. Friction is no doubt a most active means of developing electricity; we know likewise from the experiments of Wilson that the air becomes electrified by its friction against glass. It is then probable enough, as M. Koemtz § observes, that the friction of the air against the clouds and the earth develops electricity; but it may not produce any sensible effect, either on account of its want of intensity or because it is immediately dissipated by the ways of escape offered to it. [Faraday found no electrical excitement from the friction of dry air.]

* Histoire de l'Académie des Sciences de Paris, pour 1752, page 10.
† Memoire de l'Académie des Sciences de Paris, pour 1752, page 241.
‡ Memoires de l'Académie des Sciences de Paris, pour 1764, page 409.
§ Lehrbuch der Meteorologie, tom. II, page 408.

Other philosophers have limited themselves to simple conjectures. In a memoir containing his observations on atmospheric electricity, Canton* threw out in advance this question: Might not suddenly rarified air impart electricity to clouds and vapors, and would not condensed air produce a similar effect? Priestley† inquired if the empty space which is above the clouds might not always have an electricity opposed to that of the earth? May not thunder and earthquakes, he adds, be owing to a re-establishment of the equilibrium between the two electricities?

According to Beccaria,‡ electricity proceeds from the earth wherever the ground is surcharged, bearing with it the light bodies which may facilitate its passage. These bodies thus assist in transferring to the atmosphere the electricity of the earth.

Franklin§ considered the sea as the source of lightning, founding his opinion on the light which it exhibits at night on the slightest agitation. In his view, the particles of water are so many little solid spheres, which only touch the salt in some points, and he supposes there exists between these particles and those of salt, the same friction there is between the glass and the cushion of the electrical machine; so that a particle of water at the surface, being surrounded by an electric atmosphere, is repelled, and conveys to the air the electricity with which it is charged.

It was in the evaporation of water at the surface of the earth that Volta‖ sought for the cause of atmospheric electricity. According to this celebrated scientist a body on being reduced to vapor acquires a greater capacity for electricity as well as for caloric. In the case of water, the vapor in forming absorbs positive electricity and renders it latent, while the water becomes negatively electrified. When this vapor again condenses in the colder strata of air which it meets as it it rises, its electricity is disengaged, and the feeble conductibility of the air would prevent its return to the earth, from which it originated, if it were not for rain, snow, hail, or violent discharges. This theory, which was likewise adopted by Saussure,¶ is based, first, on the production of electricity in the passage of a body from one state to another. Second, on the preservation of the same quantity of electricity in a latent state by the body as long as the molecules of the latter continue in the same state of aggregation. Volta sought to verify by experiment the first of the above suppositions. Placing in communication with its condenser a metallic vase,** in which he caused water to be evaporated, he obtained, in concert with Lavoisier and

* Transactions Philosophiques, tome XLVIII, 1st part, page 357, 1753.

† Historie de Electricité, tome III, page 32.

‡ Lettere dell' Electricismo, page 202.

§ Experim. and Observ. on Electricity, page 175.

‖ Journal de Physique, tome XXIII, page 98, 1783.

¶ Voyages dans les Alpes, tome II, sec. 829, page 252.

** This experiment has been the subject of a question of priority between Volta on the one side and La Place and Lavoisier on the other. See the historical eulogy on Volta by M. Arago, Annales de Chemie et de Physique, vol. 44, page 396. We may observe that attempts had already been previously made in England to ascertain whether evaporation contributes to the production of electricity. We find in the 3d volume of the History of Electricity by Priestley, page 440, that this philosopher placed a small quantity of water on a small bit of glass and made it evaporate rapidly by means of a red-hot iron which he held under it. He did not notice that the glass acquired any sensible degree of electricity.

La Place, manifest signs of negative electricity. But as these illustrious philosophers carried on their experiments in metallic vessels which were affected by water; the results at which they arrived could not lead them to the truth, since they knew not that the slightest chemical action produces electrical effects; they therefore attributed to the change in the molecular state of bodies that which ought to have been referred to the combination of the same bodies with other elements. Hence resulted the frequent contradictions which De Saussure* obtained in repeating this experiment. When he caused water to be evaporated in an iron crucible his electrometer was electrified, sometimes positively, sometimes negatively, and sometimes even remained without presenting any signs of electricity.

Science possesses facts which philosphers have cited in support of the opinion that there is a disengagement of electricity on the change of state of bodies. Wilke observed that certain bodies, like sulphur, wax, &c., poured into glass vases, where they were left to cool, exhibit when they are withdrawn, strong negative electricity, while the glass exhibits positive electricity of equal intensity. But if the change of state were the true cause of this phenomenon, ought it not to produce electricity in the solidifying of any body whatever? Now this does not take place. M. Gay Lussac† ascertained that the adhesion of bodies and their separation by the inequality of their contraction, as is the case of sulphur and glass, wax and glass, &c., are indispensable condition for obtaining electricity after the fusion and solidifying of a body. The electricity observed in this case must then be attributed to another cause than the change of state, which appears to reside in the pressure which the two bodies exert on each other. The electrical state of steam at the moment it comes out of a boiler has been cited as favorable to Volta's theory.‡ But, though the disengagement of electricity is in this case unquestionable, still it is very difficult to attribute it to the evaporation of the water, since it is only at the instant of the expansion of the steam that the electricity is exhibited. Must we not rather refer this phenomenon to the expansion, or to some circumstance which accompanies it, such as the diminution of the pressure of the steam against the sides of the boiler? This latter opinion is strengthened by the fact that jets of atmospheric air act precisely in the same manner as those of steam. If we compress air in a vessel, such as the receptacle of a portable fountain, and then let it quickly pass off in a jet, we observe that an electrometer which is exposed to the current of air becomes positively electrified, while the vessel, if it be insulated, shows signs of negative electricity.§ Possibly it may be the same cause which produces the electricity which M. Mitchell observed during the solidifying of carbonic acid. This physisist informs us that when the acid becomes liquid by pressure and escapes from the vessel which contains it, the solid which it forms receives positive and the receptacle negative electricity. [This article was written before the publication of the researches of Faraday on the electricity of steam, which conclusively prove that the excitement is due to the friction of the particles of water,

* Voyages dans les Alpes, tome II, sec. 807, page 228, et suiv.
† Annales de Chimie et de Physique, tome VIII, p. 161, 1818.
‡ Annales de Chimie et de Physique, tome VIII, p. 161, 1818.
§ Philos. Magaz., vol. XVII, page 374, 1840.

which are mingled with the steam, against the sides of the orifice through which the steam escapes; neither dry steam nor dry air is capable of exciting electricity by friction. This is in accordance with the experiment of De Saussure mentioned at page 296 of this article.]

Atmospheric electricity being very weak before the formation of a storm, and rapidly attaining its *maximum* in the thunder-cloud, Volta concluded that the vapors which rise in the air have their electricity latent and set it free on their condensation. But nothing appears to authorize the admission that one of the electricities can be rendered latent, without the presence of the contrary, and that the one can exist insulated without the other; for it is an undoubted principle that, whenever electricity is produced, its positive and its negative states exhibit themselves simultaneously with the same intensity. These considerations appear to us sufficient to prove that Volta's theory cannot be admitted in the present state of science.

The question as to the origin of atmospheric electricity has also been the object of M. Pouillet's researches. This philosopher found, by numerous experiments, that simple evaporation produced in a platina crucible, whether slowly or rapidly, never disengages electricity when it is not accompanied by chemical action; but that it always produces electricity when the water which is evaporated holds in solution gases, acids, or salts. In this case the steam takes the positive electricity, and the solution the negative. He observed the same phenomena with solutions of alkalies; but the steam then took the negative electricity, and the alkali the positive.* Applying these results to the evaporation which takes place constantly at the surface of the earth, M. Pouillet remarked that the waters of the sea, and, in general, those which plants imbibe and those which moisten the surface of the ground, always hold in solution foreign substances, which they leave behind; and hence at the surface of the earth there is no evaporation without there being, at the same time, chemical segregation, and consequently the production of electricity. He also believed that it followed, from his experiments, that all the vapors which form at the surface of the earth are brought into an electric state, not by evaporation, as Volta supposes, but because the water, in being evaporated, leaves the foreign substances which it held in solution. This may be, according to that philosopher, one of the causes of the positive electricity which is observed in the air in clear weather.

M. Peltier,† from similar experiments, arrived at a different conclusion. He showed that, in the evaporation of saline solutions, we only obtain signs of electricity in the case of a rapid segregation of the dissolved body, produced by the action of the elevated temperature of

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* See the Journal L'Institut of October 21, 1841, No. 408.

† M. Pouillet made use of a platina crucible in order to remove the causes which might produce electro-chemical effects. This crucible, brought successively to various temperatures, was placed on a disk or metallic ring connected by a brass stem with the lower plate of a gold-leaf condenser. See his Memoir, Annales de Chimie et de Physique, tom. XXXVI, p. 5. 1827.

‡ Comptes Rendus, tom. II, p. 908, 1840; and Annales de Chimie et de Physique, tom. LXXV, p. 330, 1840 It was with a needle electrometer, described in vol. LXII of the Annales de Chimie et de Physique, that M. Peltier made his experiments.

the sides of the vessel in which the evaporation takes place; and that, in all other circumstances, we do not observe a trace of electricity whatever may be the quantity of vapor produced. Thus, in evaporating in a capsule of platina heated and connected with its electrometer a drop of a solution of sea water partly saturated, M. Peltier found that there is rarely a sign of electricity in the first experiment; but, if we recommence without having cleansed the platina, the saline layer left by the first drop being taken up by the second, and saturating it in a higher degree, the latter becomes nearly opake when it is reduced to a third of its volume. We then see a multitude of little bodies swimming in it, and, soon after, we hear decrepitations attended with saline projections which at the same instant produce in the electrometer a negative deviation. If the platina is sufficiently cooled to admit of being moistened, the decrepitation ceases, the drop extends and is at once reduced to vapor. Now, M. Peltier observed that this sudden evaporation, instead of increasing the electrical deviation, took away a part or the whole of what had been produced during the decrepitation. A third experiment produces a yet greater effect; the decrepitation is stronger and the needle forcibly deflected by the intensity of the manifestation.

It follows, therefore, that evaporation is only an adjunct in the electrical excitement, and that the electricity is due to the chemical decomposition of the hydrated molecules which adhere to the metal possessing a high temperature. Thus M. Peltier obtained the same result by substituting for salt water sea salt itself; this latter decrepitating without any aqueous fusion, the water between the molecules performing the part of the saturated solution, caused the needle of the electrometer to move. If, on the contrary, we use a salt that is unaffected by heat, and nearly insoluble, such as the carbonate of barytes, there is no electricity produced, either with or without water. Thus it appears that it is at the very moment of the separation of the combined molecules of water that the electricity is produced, and not during the evaporation of the superfluous water, as M. Pouillet believed. When this separation takes place slowly, an electric neutralization is produced before the molecules of vapor are sufficiently separated from the liquid to retain the electricity which they had at the moment of their formation; while the sudden explosions produce the isolation necessary to the preservation of the electricity developed. We know, in fact, that when the two electric fluids are separated from each other simply by chemical action, they always tend to unite again to form a neutral state, through the conducting bodies which are present.

The difference between the results to which M. Pouillet and M. Peltier arrived may be explained, perhaps, by that of the instruments which these two philosophers employed. The first used a condenser of gold leaf; he observed no signs of electricity except at the instant of the separation of the plates of the instrument; and the electricity which it then indicated was that which, being produced during the decrepitation of the substances used, had remained disguised by the opposite electricity of the upper plate. M. Peltier appears to have made his experiments with his electrometer without a condenser. By-

this instrument as he was able to seize the instant when the electricities were set free, when the disengagement ceased, and to follow step by step the phases of the phenomena, he could thus distinguish what was owing to chemical action, produced by the high temperature, from that which was due to simple evaporation.

M. Pouillet* pointed out another source of atmospheric electricity in the act of vegetation. He had established, by a series of previous experiments, that gases give off electricity when they combine either together or with solid or liquid bodies; that in these combinations, oxygen disengages positive electricity, and the combustible body, whatever it may be, negative electricity; and that reciprocally, when a compound is decomposed, each of the elements then wanting the electricity, which it has disengaged, is found in an opposite electrical state. Thus when oxygen combines with carbon, the carbonic acid which is formed is positively electrified, while the carbon remaining becomes negatively electrified. We may verify this phenomenon by placing a cylinder of charcoal perpendicularly, at about a foot below a metallic plate, connected with the upper disk of a condenser with plates of gold, and having placed its lower portion in connexion with the ground, then igniting the upper part of it, a column of carbonic acid gas immediately rises, and transmits to the upper plate an excess of positive electricity.

But we know that different parts of plants act on atmospheric air; that sometimes they form, at the expense of the oxygen, quite a large quantity of carbonic acid, which escapes insensibly, and that sometimes they exhale pure oxygen, arising from some combination in the interior of the plant. Now, if it be true, says M. Pouillet, that carbonic acid is positively electrified at the moment of its formation, it follows that plants ought to yield to the air, by the exhalation of that acid, a greater or less quantity of positive electricity. This scientist attempted to verify his conclusion directly by experiment. If the hypothesis be true, the plant ought to take the negative electricity, and M. Pouillet obtained, in fact, in the day as well as at night, signs of negatative electricity, by germinating grains in glass capsules, varnished on the outside, which were connected together by metallic wires and at the same time with the lower plate of a condenser, while the upper plate was in communication with the ground. Thus he thought he might conclude from his experiments that on a surface, in full vegetation of one hundred metres square, there was eliminated in one day more positive electricity than was necessary to charge the strongest battery.

Many philosophers have believed that the effect obtained by M. Pouillet cannot be attributed to the combination of the oxygen of the air with the carbon of the plant, since this phenomenon being analagous to combustion, the plant will set free the negative electricity, and the carbonic acid, the opposite electricity, which will immediately enter into combination with the former, if ever so little gas remains in contact with the excess of carbon. This is so far true that in the combustion of

* Annales de Chimie et de Physique, tom. XXXV, p. 405. 1827.

carbon, as observed by M. Pouillet,* we obtain signs of electricity only while the carbon, held perpendicularly, burns at its upper surface; if it be held nearly horizontally so that the carbonic acid which is formed cannot rise except by ascending along the base of the carbon, the condenser no longer becomes charged, the two electricities having had time to recombine. Now it is known that the combination of oxygen with the carbon of the plant does not take place outside of the parenchyma, but in the interior; therefore before the carbonic acid formed and remaining in contact with the carbon in excess is disengaged, the electricities that are developed ought to reunite and every sign of free electricity disappear. On the other hand it may be asked how it is that the electrical effects obtained by M. Pouillet were the same night and day. Ought they not to be different, since in the day there is the decomposition of the acid absorbed, while during the night a portion of the oxygen is transformed into acid? Further, may not these same electrical effects proceed from the remains of organic bodies which are found in the vegetable earth of the capsules, and which, decomposing by contact of air, generate carbonic acid, or rather may they not be attributed to the electro-chemical action which the same earth would naturally exercise on the conducting wires with which they may come in contact?

Vegetation is, without doubt, the result of a multitude of chemical reactions which necessarily disturb the equilibrium of the two electricities and thereby set free a portion of each; but it is very difficult to see in this the cause of the uniformly positive electricity, which manifests its presence in the atmosphere whenever the sky is clear. If, with M. Pouillet, we attribute the production of atmospheric electricity to evaporation and vegetation, the usual electrical state of the atmosphere must vary in different regions, as this philosopher† himself observes; in one place we ought to find positive electricity predominant, and in another negative. But experience is opposed to this conclusion. We do not find any notice of observations of negative electricity in clear weather, except in the report of M. Arago,‡ on a memoir containing the researches and observations made by Marshal Mormont, duke of Ragusa, during his voyage to the East. "I perceived in this memoir," says M. Arago, "three observations of negative atmospheric electricity, made at Constantinople in clear weather; three observations of the same kind at Alexandria, and three entirely similar ones made near Cairo. We do not think," adds he, "that in France, England, or Germany, any observer has ever found negative atmospheric electricity in clear weather." But if we recollect that these experiments were made by means of a conductor, which was moved slowly downward from above and upward from below until an electric effect was produced in the electroscope with which it was in communication, we see from what has been said (1 part chap. II) of the electric phenomena which the electrometers present when they

* Annales de Chimie et de Physique, tom. XXXV, page 405.
† Eléments de Physique Expérimentale et de Météorologie, tom. II, page 827, Paris, 1829.
‡ Comptes Rendus, tom. II, page 212, 1836.

are raised or lowered, how we may explain these indications of negative electricity in clear weather.

It appears to follow, from what precedes, that the phenomena which accompany evaporation and vegetation are not sufficient, in the present state of science, to explain atmospheric electricity. M. A. de la Rive* made in respect to this the following observations: "Vegetation and chemical action which take place on the surface of the globe produce so little electricity, and especially afford signs of electricity the nature of which is so variable, that we can hardly attribute to them the constantly positive electricity with which the atmosphere is charged. Moreover, these are phenomena which almost wholly cease during winter, and yet observation teaches us that the atmosphere is very frequently charged and sometimes with more electricity at this period of the year than in any other. What is then the cause which produces this agent? May it not be sought for in a more general phenomenon than any to which it has been hitherto attributed, to wit: the unequal distribution of the temperature of the atmosphere?"

The idea of regarding atmospheric electricity as a thermo-electric phenomenon had already been propounded by the philosophers who were first engaged in researches of this kind. After having ascertained the laws of electric polarity which the tourmalin acquires when its temperature is raised or lowered, Canton† advanced the opinion that heat might probably exercise an influence in the electric phenomena of the atmosphere. "If we supposed," says he, "that the air possesses qualities similar to those of the tourmalin, that is to say, the capacity of becoming electric by the increase or decrease of its heat, we can easily explain thunder-clouds, positive or negative, as well as the peals of thunder." A similar supposition was also made by Th. Ronayne,‡ in the course of his observations on atmospheric electricity.

The opinion which consists in regarding heat as the cause of atmospheric electricity has received some degree of probability from the labors of M. Becquerel. It is known that this philosopher succeeded in demonstrating that when caloric is propagated in a metallic body it produces in its whole extent such a series of decompositions and recombinations of the natural electricity that the positive electricity, successively imparted by one molecule to the next, goes from the warm to the cold part, and that the negative electricity follows the contrary course. Hence a particle which becomes warm in receiving its heat from a neighboring one, takes from the latter positive electricity and gives it negative electricity. Ought not the same effect to be produced, though in a less degree, in bodies which are bad conductors of electricity? This appears the more probable, when we recollect that the conducting power of these bodies for electricity increases with the temperature.§ M. Nobili‖ succeeded in producing thermo-electric

* Essai Historique sur l'Electricité, page 140.

† Philosophical Transactions for 1759, page 403.

‡ Philosophical Transactions for 1772, page 139.

§ M. Becquerel verified by M. Rousseau's apparatus that the glass which had been heated from 90 to 80°, and even below, becomes a conductor of the electricity even for very weak tensions.—Annales de Chimie et de Physique, tom. XLI, page 356, 1829.

‖ Bibliotheque Universelle, tom. XXXVII, page 125, 1828.

currents in bodies which are poor conductors, by merely taking the precaution of slightly moistening them. In this way he obtained very sensible deviations of the needle of a rheometer by fixing to the extremities of the wire of the latter two sticks of moistened clay, one of which, strongly heated, was placed in contact with the other, remaining at the ordinary temperature. "If we consider for an instant," says M. Becquerel,* "a portion of the atmosphere in a perfect calm, and having throughout the same temperature, the state of equilibrium of its electricity would not be disturbed; but if, by any cause whatever, it should happen to be penetrated by a current of cold air, a part will become cool, take the negative electricity, and the other part the positive electricity. The contact of the molecules being short in duration, by reason of the rapidity of the current, every one of them would preserve a part of the electricity which is disengaged during the change of the temperature. If the portions which have become cooled enclose aqueous vapor, this will become condensed, imbibe electricity, and form a cloud charged with negative electricity. When the cold current of air contains vapor, a cloud will be found possessing positive electricity. It has been observed that in general the air which is at a certain distance from houses and trees, possesses positive electricity. This is evident, for the cold air which is found in contact with the earth, after being heated at its expense, is raised on account of a less specific gravity, and bears with it the positive electricity which it has taken during its heating." It is probable that effects of this kind take place in the atmosphere. Experience and observation only can decide in what degree they concur in the production of the electrical phenomena of the air.

We see from the foregoing how little we have advanced in our knowledge of the origin of the positive electricity of the air in clear weather. In examining this question, M. Peltier† offers a new opinion, according to which the air is completely deprived of electricity, while all the electric phenomena of the atmosphere derive their source from the negative electricity of the earth. In describing the experiments previously mentioned, in which an electrometer diverged positively when it was raised, and negatively when lowered, he presents his mode of considering atmospheric electricity. "These experiments," says he, "demonstrate that the earth acts as a body powerfully negative, and the celestial space as a body strongly positive, and all the bodies interposed between them become electrified by induction, according to their position and relations with the earth, and not by contact with the air. When a person is in an uncovered place, and under a clear sky, his head is in a negative state, as are the upper ends of all bodies, such as the tops of trees. This negative tension changes with our position, with the state of the sky, and the shelter which cover us. This electric induction is proved by placing the hand raised above an insulated globe screwed to the upper part of the electrometer. The leaves of gold diverge somewhat negatively. This effect is reproduced with force when there prevails one of those red-

* Annales de Chimie el de Physyique, tom. XLI, page 372.
† Compte's Rendus, tom. XII, page 307. 1841.

dish dry fogs which are strongly negative; they act at a less distance and produce a greater inductive effect. These fogs show also what a series of discharges would be produced between the gold leaves and the armatures, if it were the air which was the electrified body."

These experiments place beyond doubt the existence of the negative electricity of the earth, of which M. Peltier speaks. It had previously attracted the attention of De Saussure,* who, by a particular arrangement of his electrometer, sought to ascertain its variations. The most direct means of determining it consists in placing one of the ends of a platina wire of a rheometer in a moist part of the ground, and the other in a dry portion of the same ground or under an adjoining building. This part of the ground or of the building being, on account of its partial conductibility, less charged with electricity than the moist ground, the electrical equilibrium is established between the two by the means of the metallic wire, and results in an action on the magnetic needle. In this way M. Peltier† ascertained that during clear weather the ground is constantly negative at very different tensions, according to the hygrometric state and temperature of the air. But if it be true that the earth possesses a negative electricity, and that an electrometer placed under a clear sky becomes electrified by induction, and not by contact of the surrounding air, must we conclude, with M. Peltier, that the air is wholly deprived of electricity? This philosopher introduced the positive induction of celestial space in the electrical phenomena of the atmosphere; but he used this language only that he might be the more easily understood. According to him, ponderable bodies only have the power of controlling the cause of electric phenomena. Empty space, therefore, can control nothing. The earth, as a ponderable body, possesses the power of coercion which M. Peltier calls negative electricity, while celestial space, not being able to control this cause, owes to this negative quality an electric reaction, which he calls vitreous electricity. Further, this philosopher admits neither the theory of the two electric fluids nor that of one fluid; but he regards the cause of electric phenomena, the same as that of light and heat, as a modification of a universal fluid which fills all space, and the terms of "vitreous" and "resinous" have for him no other meaning than that of indicating the different degrees of one and the same state, beginning at a point of equilibrium deprived of all electric manifestation. It is by these considerations that he explains the phenomena which the electroscopes present when they are raised or lowered. This interpretation of atmospheric electricity is then joined to a new theory of electricity, which M. Peltier has hitherto only indicated, and of which he promises afterwards to furnish all the details. However this may be, it appears that the different methods of managing electroscopes under a clear sky could likewise be explained by the theory of two electric fluids and by the hypothesis of different atmospheric strata progressively electrified. We might, however, ask how it happens that an electroscope which has been brought to an equilibrium presents no diver-

* Voyages dans les Alpes, tom. II, § 830, page 254.
† Traité de l'Electricité et du Magnétism, par Becquerel, tom. IV, p. 107.

gence by its contact with the air, if it is the latter which becomes electrified? We believe that the explanation of this fact may be derived from what we have said (part 1, ch. II) in quoting the opinion of M. Gay Lussac on the distribution of the electricity of the atmosphere; besides, we ought to remember that the lower strata of the air can possess, in a free state, but a feeble quantity of electricity. Many causes may, in fact, be opposed to the accumulation of free electricity in these strata. In the first place, there is the proximity of the ground, which, charged by induction with an electricity contrary to that of the air, reacts consequently, by its attraction, to neutralize it. Another cause is found in the great conductibility which the air of the same strata naturally possess in consequence of the elevated temperature to which they are subjected, and the approach of the molecules of water to the state of vapor, circumstances which permit an easy escape for all the free electricity. In fine, even though it should be supposed that the air of these strata could contain a greater quantity of free electricity, it appears, according to the experiment of Mr. Faraday and that of M. Peltier himself, that the electric action being the same in every direction, no divergence could take place in the instrument.

CHAPTER II.

OF THE VARIATIONS OF ATMOSPHERIC ELECTRICITY IN CLEAR WEATHER.

§ I. *Of the influence of local causes and of the height on atmospheric electricity in clear weather.*

By means of his electrometer, furnished with a metallic stem, De Saussure* observed that local causes exercised a very decided influence on the electrical indications obtained under a clear sky. He discovered that they did not become sensible in the open plain, except at a height of from 4 to 5 feet above the ground; that they are stronger in the most elevated and isolated places; there are none in houses, under trees, in streets, in courts, and, in general, in localities wholly inclosed; that, nevertheless, in cities they are sensible in the midst of large, open places, on quays, and especially on bridges where they have been found more powerful than in the open country.

These results are confirmed by the observations which Schübler† made during a journey in which he twice crossed the chain of the Alps separating Germany from Italy. He always observed an increase in the intensity of atmospheric electricity in proportion as the places which he passed through were more elevated and isolated, and this increase was so much the more remarkable the farther he was removed from forests and habitations. Thus, on the 13th of April, 1813, at 4 o'clock in the evening, the electric tension at Mount St.

* Voyages dans les Alpes, tom. II, § 792, page 205, and § 800, page 219.
† Journal de Schweigger, tom. IX, pages 348 and 350, 1813.

Gothard, 6,200 feet above the level of the ocean, was only + 10 degrees of Volta's electrometer, but the instrument rapidly passed to 50 and even to 60 degrees when it was placed on a granite rock 30 feet high, which was found near the place where the observation was made. The same instrument ordinarily indicated only 4 or 5 degrees at the same time of the year, and at the same hour of the day, in the low part of the same country.

Though Schübler could not discover any direct relation between the intensity of atmospheric electricity and the height of the place above the level of the sea, yet he thought that this relation existed, but that it was influenced by a multitude of causes. He believed he could not be mistaken in general as to an increase of electricity with the height, as is manifest in the following table, which contains the result of his experiments made under a clear sky on the inclinations of an Alpine mountain:

Height above the valley.	Height above the surface of the ocean.	Degrees of electricity.	Observations.
Feet. 30	*Feet.* 1,830	+ 5	At the foot of the mountain, at 6 feet above the ground.
42	1,842	+ 9	Isolated station, 12 feet above the ground.
98	1,898	+ 24	On a height about 20 feet above the ground, far from trees.
110	1,910	— 4*	Near a small fall of water.
195	1,995	+ 27	Isolated place, 20 feet above the ground.
205	2,005	+ 18	On a small height, at 8 feet above the ground.
202	2,002	+ 10	In the same place, 5 feet above the ground.
500	2,300	+ 32	On a height, far from trees, 10 feet above the ground.
510	2,310	+ 20	At 10 feet from the ground, near a forest.
730	2,530	+ 30	On a level soil, isolated, 10 feet above the ground.
724	2,524	+ 13	The same station, at 4 feet above the ground.

De Saussure† found, on the contrary, atmospheric electricity weaker on mountains than in the plains. Thus, according to him, it is rather the relative height of the place of observation than its absolute height, which exercises an influence on the indications of the instruments.

The mode of action of atmospheric electricity on the electrometer, and the negative electricity which terrestrial bodies possess, explain the influence which local causes exert on that instrument. Though in general the electrometer gave no indication in places which were sheltered, we ought, however, to remark, that it might give indications under trees or near buildings which are in the neighborhood of uncovered places, but then these indications are negative. This happened when, after having brought the instrument to an equi-

* We shall hereafter see the cause of this negative electricity.

† Voyages dans les Alpes, tom. IV, sec 2008, p. 197, and sec. 2055, p. 257.

librium, it is moved horizontally toward these bodies. If the sky is clear, there is observed a negative divergence, which reached its *maximum* when the instrument had come under a tree, or as near as possible to a building; while it returned to zero every time it is carried back to the place from which it started. This observation, which appears to have been reported for the first time by M. Erman,* may be explained by observing that when the electrometer was brought into an equilibrium under a positive influence its stem remained in possession of the negative electricity, which, repelled by that of the same name possessed by the tree or building, produces the divergence which is observed.

The intensity of the electricity increases in proportion as we recede from the surface of the earth. This increase was proved by the philosophers who first engaged in this kind of research. De Romas,† Cavallo,‡ and others obtained signs of electricity, the more powerful as the kite which they used rose to a greater height. Science possesses hitherto few data in respect to this fact. Schübler sought to verify it by observing the degrees of an electrometer, placed at increasing heights on the side of a tower, so as to leave as nearly as possible the same distance of five feet between its stem and the wall. The following table shows the result of his experiments, which were made under a clear sky, and at a temperature of 20° centigrade:

Perpendicular height above the ground.	Degrees of the electrometer.	Observations.
Feet.		
30	+ 15	
50	+ 20	
75	+ 26	
86	+ 18	These observations were not made at a sufficient distance from the wall.
115	+ 22	
145	+ 50	
152	+ 53	
171	+ 58	
180	+ 64	

By a series of experiments made with a kite, the string of which could at pleasure be connected with an electrometer or with a rheometer, M. Peltier§ discovered an important fact relative to the increase respecting which he was inquiring. He observed that the electrometer indicated an increasing positive electricity for 10 feet, while the first indications of the rheometer did not take place except at a height of 131 feet. From 131 to 328 feet the needle moved feebly; but beyond this height, even up to that of 810 feet, which was the

* Journal de Physique, tom. LIX, p. 101. 1804.
† Mémoires des Savants Etrangers, tom. II, p. 406. 1755.
‡ Traité complet d'Electricité, p. 294.
‖ Journal de Schweigger, tom. IX, p. 351.
§ Comptes Rendus, tom. X, p. 712. 1840.

maximum of height which the kite could attain, the deviation increased so that the needle struck the check at 90°, and was maintained between 70° and 80°, consequently the current had at least a force of 600 proportional degrees of the electrometer. Thus, then, under a clear sky the intensity of atmospheric electricity increased slowly up to a certain height, beyond which it increased with very great rapidity. Another fact, not less important, is the existence of a stratum of negative air interposed between the positive strata, a fact which M. Peltier observed when in the course of warm days light clouds were formed. The reverse of the sign in atmospheric electricity was exhibited for the first time April 21, 1840. The sky was quite clear, except that here and there the vapor formed into long cirrus clouds, which moved slowly from the south, while the lower wind was from the northwest. The kite reached the height of 100 feet, and the rheometer had as yet given no signs of a current, though the electrometer had indicated an increasing positive tension at the height of 10 feet. At from 100 to 164 feet the rheometer deviated from 2° to 3°, and indicated a descending positive current. Above this height the two instruments remained an instant without giving any electric sign, after which the rheometer indicated a descending current of 2° or 3°, but negative. The electrometer assigned to this negative zone a thickness of about 66 feet, above which the positive electricity reappeared. The new positive current, of which notice was given by the rheometer, was at first feeble; but the kite being raised to 394 feet, the needle began to move rapidly. When it had reached 590 feet, the current showed 60°, corresponding to 160 proportional degrees.

Some experiments on atmospheric electricity at different heights in the air have also been made by Messrs. Becquerel* and Breschet, on one of the plateaus in the vicinity of the Great St. Bernard, by means of an arrow provided with a conducting wire, the extremity of which communicated with a straw electrometer. The results at which these philosophers arrived prove, 1. That on high mountains, in clear weather, the electricity increases in intensity from leaving the ground up to the height of at least 262 feet, the limit to which the observations were carried; 2. That this electricity always remains positive, without any appearance of change of sign.

We ought also to mention the experiments which Messrs. Gay Lussac and Biot† made during their ærostatic ascension. These philosophers likewise found atmospheric electricity increasing with the height; but it appeared to them negative, though the sky was perfectly clear. This result is not surprising, if we consider that the mode of experimenting adopted in this case consisted in suspending, by one end, a metallic wire of 164 feet long, terminated at the lower end by a ball of metal, and that it was the electricity at the top of the wire which was observed. This electricity would, then, be of the same nature as that produced by a charged plate held over the point or the ball of an electrometer; the point or ball would be charged negatively by the positive induction of the plate. M. Biot*

* Traité de l'Electricité et du Magnetisme, tom. IV, pag. 110.

† Journal de Physique, tom. LIX, pages 315 and 318.

has shown in this way that the result may be very well interpreted by the hypothesis of atmospheric strata more intensely electrified with height, since then the upper strata, more strongly charged with positive electricity, exercise on the metallic wire an action of induction more powerful than that produced by the electricity of the lower strata.

§ II.—*Of the diurnal and annual variations of atmospheric electricity in clear weather.*

Le Monnier† first observed that in the same place positive electricity in clear days was subject to regular variations of intensity. He noticed that it diminished by degrees towards sunset, and finally at last disappeared one or two hours afterwards, and did not reappear till towards eight or nine o'clock in the morning. He at first attributed this daily variation to the moisture of the night, which rendered the insulation of his apparatus less perfect; but after taking suitable precautions he ascertained that there was another cause for this phenomenon. Beccaria,‡ Gardine,§ Crosse,‖ and other observers arrived at the same result. De Saussure¶ determined the laws of this daily period by means of observations made with his electrometer, armed with a conductor terminating in a point. He observed that it presented two *maxima*, which followed some hours after the rising and setting of the sun, and two *minima*, which preceded the rising and setting of the same luminary. "In winter," he says, "the season during which I have most successfully observed the electricity of clear air, it appears to me that the hours when it is most feeble are those which are comprised between the time when the evening dew has wholly completed its fall and that when the sun has risen. Next, its intensity increases gradually and reaches, almost always, before noon a definite *maximum*, after passing which it seems to decrease until it is renewed at the fall of the dew, a period at which it is sometimes stronger than during the day. After this it diminishes gradually during the night, without, however, becoming null when the weather is clear." The observations which Schübler** continued for a whole year, at Stuttgard, lead to the same result. They showed that when the weather is clear atmospheric electricity, which is very feeble before the rising of the sun, afterwards increases at first slowly, then rapidly, until it reaches its first *maximum* some hours after; that it also diminishes, at first rapidly, then slowly, until it has reached its *minimum*, some hours before the setting of the sun; that it begins again to increase when the sun approaches the horizon, and attains its second *maximum* some hours after its setting; to diminish again during the rest of the night.

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* Traité de Physique Expérimentale et Mathématique, tom. II, page 455.
† Mémoires de l'Académie des Sciences de Paris pour 1752, page 241.
‡ Lettere dell' Electricismo, page 166.
§ De influxu Electricitatis Atmosph., §§ 50 and 51.
‖ Bibliothèque Britannique, Sciences et Arts, tom. LVI, page 524, 1814.
¶ Voyages dans les Alpes, tom. II, § 802, page 221.
** Journal de Schweigger, tom. III, page 123, and tom. VIII, page 21.

The electrical periods determined by the observations of Mr. Clarke,* of Dublin, are somewhat different. According to him, the first *minimum* takes place at three o'clock in the morning; the electricity then increases till ten o'clock; it then slightly diminishes till eleven o'clock, then increases anew till two o'clock and forty-five minutes in the evening; at three o'clock it begins again to decrease, but more rapidly than the first time, till five o'clock; it then increases till seven o'clock; then rapidly decreases till it has reached its *minimum* at three o'clock next day.

In order to exhibit more clearly these periods of atmospheric electricity, we quote the observations which were made by Schübler† on the 11th day of May, 1811, at very short intervals of time, and under a sky constantly clear. We shall follow them by a series of analogous observations, for which we are indebted to De Saussure,‡ and add some of those which were made by M. Arago§ at the observatory of Paris by means of the straw electrometer.

Observations by Schübler.

Hours.	Degrees of the electrometer.	Hygrometer of Saussure.	Hygrometer reduced to 18°.7 centig.	Thermometer.	State of the sky.
	°	°	°	°	
4 a. m	+ 5	88	72.5	+ 9.3 R.	Perfectly clear; gradually the sky became vaporous; dew was formed.
5 a. m	6½	88	75.4	9.5	
6 a. m	8	87	77.4	10.5	
7 a. m	11	86	80.8	12.1	
8 a. m	13	84	82.7	13.5	
9 a. m	10	76	77.9	15.5	The horizon completely cleared up; the color of the sky became a pure blue.
10 a. m	8	70	73.9	17.0	
12 a. m	7	63	71.7	20.1	
2 p. m	6½	61	71.6	21.6	
4 p. m	5½	60	70.1	21.3	
5 p. m	5	62	71.9	20.9	
6 p. m	6.0	65	73.9	20.0	Vapors and evening dew formed again.
7.30 p. m	8.0	72	77.0	17.5	
8.30 p. m	12.0	83	84.2	15.5	
9.30 p. m	8	86	80.4	13.0	Perfectly clear.
10.30 p. m	7	88	79.8	12.1	
12 p. m	6½	88	72.1	11.0	
2 a. m	5½	88	74.2	10.1	

* These observations were undertaken at the request of the Royal Irish Academy, and were continued during a whole year.—Philosophical Magazine, vol. XVI, pages 224 and 228, 1840.

† Journal de Schweigger tom. III. Beilage.

‡ Voyages dans les Alpes, tom. II, § 802, page 224.

§ Traité de l'Electricité et du Magnétisme, par Becquerel, tom. IV, page 93.

Observations by De Saussure.

Hours.	Electrometer.	Hygrometer.	Thermometer.	State of the sky.
Feb. 21, 1785.	°	°	°	
9. 15 a. m	+2. 0	89. 3	—8. 3	Pale sun; fleecy clouds.
11. 10 a. m	1. 6	83. 9	4. 3	Fine sun.
2. 10 p. m	1. 1	69. 6	0. 2	Fine sun.
5 p. m	1. 1	77. 2	2. 3	Sun setting.
6 p. m	1. 0	85. 0	5. 2	Some clouds in the southwest.
7 p. m	1. 8	89. 0	6. 8	Perfectly clear.
8 p. m	2. 0	95. 0	10. 0	Perfectly clear.
9 p. m	1. 8	97. 5	10. 6	Perfectly clear.
10 p. m	1. 2	95. 0	9. 9	Little clouds towards the horizon at the south.
11 p. m	1. 5	99. 1	12. 3	The same, more extended towards the southwest.
12 p. m	1. 2	Hoar frost.	12. 5	The same, more extended towards the southwest.
Feb. 22, 1785.				
1 a. m	0. 9	do.	14. 3	The same, more extended towards the southwest.
2 a. m	1. 2	do.	14. 5	Clouds increase and approach each other.
6. 15 a. m	0. 8	do.	15. 0	Clear.
7. 30 a. m	1. 2	do.	14. 7	Fogs, very light.
8. 10 a. m	1. 1	do.	14. 2	Fogs, very light.
9. 10 a. m	1. 6	do.	10. 7	Fogs, very light.
10. 10 a. m	2. 2	do.	8. 2	Fogs, very thick.
11. 10 a. m	1. 8	do.	4. 8	Fogs, very thick.
1. 10 p. m	1. 7	do.	4. 9	Fogs, very thick.
2. 20 p. m	1. 4	82. 0	+0. 6	Fog, thin; sun pale.
3. 30 p. m	1. 1	81. 9	—0. 9	Weather, half cloudy; sun pale.
5 p. m	1. 2	89. 0	4. 3	Half cloudy.
6 p. m	2. 2	91. 2	4. 6	More cloudy.
7 p. m	1. 7	94. 0	6. 1	Half cloudy.
8 p. m	3. 7	94. 0	5. 9	Cloudy; fogs at southwest.
Feb. 23, 1785.				
0. 45 a. m	1. 0	95. 0	4. 1	Cloudy; more foggy.
8. 5 a. m	1. 2	81. 3	1. 0	Cloudy; more foggy.
10. 7 a. m	0. 8	76. 0	0. 0	Cloudy; more foggy.
3. 45 p. m	0. 8	76. 0	+0. 5	Cloudy; sun very pale.
5 p. m	1. 0	75. 3	—0. 3	Cloudy.
6 p. m	0. 8	74. 0	0. 7	Cloudy.
7 p. m	2. 2	79. 7	1. 7	Almost perfectly clear.
8 p. m	1. 7	87. 3	3. 7	Half cloudy.
12 p. m	0. 5	92. 0	3. 0	More cloudy.

Observations by M. Arago.

Hours.	Electrometer.	State of the sky.	Winds.
	°		
March 3—7.20 a. m.	+0.50	Clear	E.
7.30 a. m.	1.45	--do	E.
7.50 a. m.	2.30	--do	E.
8 a. m.	1.00	--do	E.
8.30 a. m.	2.60	--do	E.
9 a. m.	6.25	--do	E.
9.50 a. m.	5.10	--do	E.
9.45 p. m.	3.00	--do	E.
9.15 p. m.	0.85	--do	E.
March 6—7.30 a. m.	*1.50	--do	SE.
7.45 a. m.	0.75	--do	SE.
8 a. m.	9.50	--do	SE.
8.30 a. m.	6.00	--do	SE.
9 a. m.	15.00	--do	SE.
9.15 a. m.	23.50	--do	SE.
10.20 a. m.	9.00	--do	SE.
5.45 p. m.	0.00	--do	E.
7 p. m.	0.20	--do	E.
9.50 p. m.	10.00	--do	E.
March 14—7.40 a. m.	+1.65	--do	W. SW.
8 a. m.	3.25	--do	W. SW.
8.20 a. m.	14.00	--do	W. SW.
8.30 a. m.	18.00	--do	W. SW.
8.45 a. m.	24.00	--do	W. SW.
9 a. m.	†26.00	--do	W. SW.
10 a. m.	21.00	--do	S. SW.
11.15 a. m.	5.25	--do	S. SW.
12 a. m.	2.00	--do	S. SW.
0.45 p. m.	4.50	--do	S. SW.
1.20 p. m.	5.50	--do	S. SW.
1.40 p. m.	3.00	--do	S. SW.
5.45 p. m.	0.00	Vaporous	S.
6.45 p. m.	0.20	--do	S.
7.15 p. m.	2.00	--do	S.

The hourly observations of Schübler indicate a first *minimum* at four o'clock in the morning, a first *maximum* at eight o'clock, a second *minimum* at five o'clock in the evening, and a second *maximum* at eight and a half o'clock in the evening.

If we look at the first eighteen observations of De Saussure, which include from twenty-four to twenty-five hours, during which the sky remained almost clear, we see that at first the electricity was quite strong towards nine o'clock in the morning; that it decreased gradually till six o'clock, when the first *minimum* was exhibited; it then increased till eight o'clock, when it reached the second *maximum*; and then it decreased anew till the time of the second *minimum*, which took place about six o'clock the next day. We do

* Deviation variable. † More than 26°.

not subsequently observe as much regularity in the electrical periods on account of the cloudy weather.

The observations of M. Arago indicate a first *maximum* toward nine o'clock in the morning; but as all the observations of the succeeding hours have not been collected, we cannot determine the hour of the second *maximum*, nor the hours of the two *minima;* still we can always establish their existence.

Schübler* found that the electrical *maxima* and *minima* do not always take place at the same hour of the day. They vary, particularly with the periods of the rising and setting of the sun; in the longest days of summer the first *maximum* appears sooner, and in the shortest days it happens later, and approaches the hour of noon; the second *maximum*, on the contrary, is retarded in the first instance, and happens sooner in the second. It follows that the greatest distance between the first *maximum* and the second fall in the middle of the summer, and the least in the middle of winter, when the two *maxima*, especially in a cold and cloudy day, appear blended together. This result does not at all accord with that which De Saussure† deduced from his observations. "Generally in summer," he says, "when the earth is dry, on account of the drought of the preceding weather, and when a day occurs which is clear, dry, and warm, the electricity of the air goes on increasing from the rising of the sun, when it is nearly imperceptible until towards three or four o'clock in the afternoon, when it acquires its greatest force. It then gradually decreases till the moment of the fall of the dew, when it increases again, then diminishes, and finally ceases entirely in the night."

We ought, however, to remark that Schübler‡ sometimes observed that the *maximum* happened later than ordinary in the morning, and sooner in the evening, when the temperature of the air was colder than usual at the same season. He observed this phenomenon also during a severely cold winter, and in some cool days of summer. However this may be, we give the mean periods of the two *maxima* and of the first *minimum* for the different months of the year, such as follow from the observations of this philosopher. As for the second *minimum*, which happens in the afternoon, Schübler found in all his observations the same period of two o'clock, because atmospheric electricity at that hour is very near its *minimum* in all seasons, and in winter it coincides with it.

* Journal de Schweigger, tome VIII, page 25.
† Voyages dans les Alpes, tome II, § 803, page 225.
‡ Journal de Schweigger, tome VIII, page 26.

Months.	First minimum, morning.	First maximum, morning.	Second maximum, evening.
June, 1811	From 4 to 5 o'clock	7½ to 6 o'clock	10 o'clock.
July, 1811	5 o'clock	6½ o'clock	9½ o'clock.
August, 1811	5 o'clock	7½ o'clock	8½ o'clock.
September, 1811	7 o'clock	8 o'clock	8 o'clock.
October, 1811	7 o'clock	8½ o'clock	7½ o'clock.
November, 1811	7 o'clock	9 o'clock	7 o'clock.
December, 1811	8 o'clock	10 o'clock	6 o'clock.
January, 1812	7 o'clock	10 o'clock	6 o'clock.
February, 1812	7 o'clock	9 o'clock	7 o'clock.
March, 1812 (1)	6½ o'clock	8½ o'clock	7½ o'clock.
April, 1812	6 o'clock	8 o'clock	8 o'clock.
May, 1812	5 o'clock	7 o'clock	9 o'clock.

(1) In his observations on atmospheric electricity made during clear days of the month of March, 1830, M. Arago found that the mean hour in respect to the first *maximum* was about 8*h*. 48*m*. for the same month.

These observations show that the different periods of the year exert a striking influence on the intensity of atmospheric electricity in clear weather as indicated by the electrometer. This fact was previously established by Cavallo,* who found the intensity with which it acted greater in cold weather than in warm. Volta† observed that in winter his electrometer indicated from ten to twenty degrees as the *maximum* of the morning, that it often indicated eight degrees towards the hour of sunrise, while in summer the *maximum* of the morning rose to only six degrees, and that of the evening to eight. De Saussure‡ observed, likewise, that atmospheric electricity is much weaker in summer than in winter; at the latter period of the year, in the open country, he observed the small balls of his electrometer diverge two lines, whereas in summer their greatest separation was but one line. This circumstance was especially to be noted in Schübler's§ observations, as may be seen by the following table, which includes the mean intensities of the electricity of clear air at mean periods of the *maxima* and *minima*, as well as the general mean and absolute *maximum* of each month.

* Traité complet d'Electricité, page 293.
† Dictionnaire de Gehler, tome VI, page 475.
‡ Voyages dans les Alpes, tome II, § 803, page 225.
§ Journal de Schweigger, tome VIII, page 21.

Months.	Mean monthly forces of atmospheric electricity.								Absolute monthly maximum.	Mean monthly force.	Mean monthly temperature.
	Hours.	First minimum.	Hours.	First maximum.	Hours.	Second minimum.	Hours.	Second maximum.			
		°		°		°		°	°	°	°
1811.											
June	4 to 5	+ 5.64	7½ to 6	+ 12.85	2	+ 3.92	10	+ 12.00	+ 16	+ 8.60	+ 15.8 R
July	5	4.87	6½	13.50	....	4.56	9½	14.43	22	9.34	16.6
August	5	5.87	7½	15.93	....	5.47	8½	10.11	25	10.84	14.3
September	7	5.54	8	15.43	....	5.00	8	15.61	25	10.39	11.3
October	7	7.25	8½	15.35	....	6.28	7½	19.71	28	12.14	11.3
November	7	5.50	9	14.42	....	8.22	7	17.44	30	11.39	5.1
December	8	12.40	10	18.80	....	12.85	6	20.71	35	16.19	1.5
1812.											
January	7	14.75	10	31.00	....	19.10	6	31.88	40	24.17	— 2·4
February	7	7.54	9	25.55	....	16.27	7	24.54	55	18.47	+ 3.0
March	6½	5.37	8½	13.00	....	6.42	7½	14.00	21	9.69	3.8
April	6	4.00	8	14.75	....	4.75	8½	7.58	25	7.77	4.3
May	5	4.15	7	13.00	....	4.33	9	10.27	20	7.93	11.1
Means	......	+ 6.90	....	+ 16.96	....	+ 8.09	....	+ 17.01	+28.5	+12.24	+ 7.9 R

In going over this table we perceive that the intensity of electricity for the two *maxima* and for the two *minima* increase perceptibly from the month of July to the month of January, inclusive; consequently that the greatest intensity appears in the winter and the smallest in summer. Moreover the proportion of the mean *minimum* to the mean *maximum* is nearly double in the months of summer compared to those of winter, as may be seen in the following table, which comprises the report for the different months of the year, and in which the mean *minimum* is constantly taken as the unit:

1811,	June	1 : 2.59
"	July	1 : 2.94
"	August	1 : 2.82
"	September	1 : 2.94
"	October	1 : 2.59
"	November	1 : 2.32
"	December	1 : 1.56
1812,	January	1 : 1.80
"	February	1 : 2.10
"	March	1 : 2.29
"	April	1 : 2.55
"	May	1 : 2.74

§ 3. *Of the probable causes of the periodical variations of atmospheric electricity in clear weather.*—Many physicists have endeavored to ascertain the cause of the daily variations of atmospheric electricity when the weather is clear. De Saussure,* observing that they were in propor-

* Voyages dans les Alpes, tom. II, sec. 831, p. 256.

tion to the hygrometric state of the air, gave the following explanation: "Towards the end of the night the electricity appears very feeble, either because the evaporation is nearly nothing, or because the moisture of the preceding evening and that of the night which followed it have transmitted to the earth nearly the whole electric fluid accumulated in the air. But when the sun begins to warm the earth again the electricity of the atmosphere increases, because the vapor which the heat causes to rise from the earth conveys electricity into the air, and transmit, in part, that which begins to accumulate. But when the sun reaches a certain height the heat increases in a greater degree than the evaporation; the air is dry, and transmits with difficulty the electric fluid accumulated in the height of the atmosphere. It follows that our electrometers, placed near the surface of the earth, indicate a decrease of electricity, although the electric fluid continues to accumulate in the elevated regions. Again, as the sun approaches the end of his career the air is cooled, becomes damp, and begins to transmit more abundantly to the earth the electric fluid accumulated in the higher regions. The electrical intensity must then increase with the moisture until two or three hours after sunset. Finally, when the air begins to be exhausted of its moisture the electricity decreases anew until the next day." De Saussure, according to the same principle, explains why atmospheric electricity is much less powerful in summer than in winter. The air in the first case being warm and dry resists with more force the escape of the electric fluid accumulated in the upper regions of the atmosphere; while in the winter the moist air must produce a contrary effect. He thought that the accumulation of free electricity, in summer, in the elevated regions of the atmosphere is probably one of the causes of the frequency of thunder storms in this season.

This manner of accounting for the daily variations of atmospheric electricity, which M. Becquerel* and other philosophers have also adopted, rests on the development of electricity during the evaporation of water—a phenomenon which does not appear sufficiently proved in the present state of science, as we have heretofore shown. It supposes, also, that an electrometer is charged by the contact of the surrounding air; and we have seen, according to M. Peltier, that the contrary is true. Besides, it is difficult to conceive how vapor can transmit the electricity with which it is charged to the higher strata of the atmosphere at the same time that it transfers towards the earth that which is accumulated in these same strata. Finally, among the lower moist and conducting strata there must be found other strata sufficiently dry, and consequently so imperfect in their conducting power as not to permit the transmissions of electricity.

Schübler's observations establish a direct relation between the daily variations of the electricity of the air and those which occur in its state of relative moisture. In fact, if we examine the table which contains the hourly observations made by this philosopher on the 11th of May, 1811, we see that atmospheric electricity is at its *minimum* a

* Traité de l'Electricité et du Magnétisme, tom. IV, p. 102.

little before sunrise, and that it increases but slowly during the rising of this luminary, the increase being very small in the first hour; at the same time the hygrometer advances but little at first, and in a manner barely perceptible, towards dryness. Soon after the electricity increases rapidly, and it attains (some hours later) toward eight o'clock its first *maximum*. At this time of day the temperature of the air rises quite rapidly; the hygrometer likewise advances some degrees towards dryness; but if we reduce by calculation its indications to the same temperature, it is found that the absolute moisture of the air, instead of decreasing, rather increases in the first hours which follow sunrise. When the electricity has reached its first *maximum* and begins to decrease, the lower strata of the air lose their moist condition; the atmosphere becomes clear, and the sky assumes insensibly a pure blue. It is also at this period that the dryness of the air becomes real, which is clearly announced by the hygrometer. About two o'clock in the afternoon the electricity is very feeble, and near its second *minimum;* it contributes to decrease a little in summer, until towards four or five o'clock. Now, we may observe that this is precisely the period of the greatest real dryness in the air. An hour before sunset the electricity begins anew to increase, though slowly; it shows itself more and more in proportion as the sun descends; and a little time after it disappears below the horizon it increases more rapidly, and soon after reaches its second *maximum;* also, during this time light vapors appear in the atmosphere. At sunset the air had lost its transparency, the moisture rapidly increased, the freshness of the evening came on, and the dew is formed. From this moment the electricity decreases with the actual moisture of the air.

The relation between the progress of atmospheric electricity observed by Schübler and that of the hygrometric state of the air in the course of the day is then evident. It is the same for the periods of the mean *maxima* and *minima* of the year; for, if we examine the table which contains the intensities of the electricity for the different months, we observe that the intensity is the strongest in the month of January and most feeble in the months of April and May. Now, it is precisely the same periods which exhibit the extremes of the relative humidity of the air.* It is, therefore, no longer doubtful, as De Saussure was the first to observe, that the daily variations of atmospheric electricity are only the result of the changes which take place in the hygrometric state of the air. Schübler† advanced the same opinion; but, admitting Volta's theory, he found the explanation in the electricity which the vapor conveys to the air in a latent state, and which it set free at the moment of its passage to the state of vesicles.

We know that it is not in the greater or less quantity of positive electricity conveyed by the vapor of the atmosphere that we must seek for the cause of the daily variations of the electricity, since the circumstances which attend the formation of vapor give the air sufficient conducting power to produce the decomposition of the electric fluids liberated at the instant.—(See page 316.) We know, further, that

* Lehrbuch der Meteorologie, von L. F. Kaemtz, tom. I, p. 337.
† Journal de Schweigger, tom. VIII, p. 29.

the divergence of the gold leaves or straws of an electrometer is owing to a superior positive induction, and not to the electricity which the surrounding air has communicated to this instrument. Finally, if we recollect that the presence of an ignited body is sufficient to render this divergence greater, we may perhaps conclude that the daily variations of atmospheric electricity, such as have been observed by De Saussure and Schübler are only in a great degree the effect of changes which, during the course of the day, take place in the electric radiation of the electrometer. In fact, these changes depend directly on the greater or less facility with which the negative electricity can escape, and consequently on the conductibility of the air. Everything which tends to increase this conductibility will favor the electric radiation, and consequently the divergence of the gold leaves produced by the repelling electricity; on the contrary, everything that diminishes the conductibility also weakens the radiating power and the divergence of the instrument. But as the conductibility of the air is in its turn dependent on the quantity of vapors it contains, it appears to us that an electrometer with a metallic rod ending in a point, would give in the same circumstances, that is to say, under a clear sky, indications in direct accordance with the hygrometric state of the air. Accordingly, the electric radiation, and consequently the divergence of the gold leaves, will increase at sunrise, on account of the vapor which rises in the air, and render this medium a better conductor of electricity; it will be the same in the evening towards sunset, when the decrease in the temperature will produce the condensation of the vapor which is in the lower strata of the air. Toward the middle of the day, on the contrary, the warmer air is at the same time dryer and consequently a poorer conductor of electricity; hence the radiation of the electrometer as well as the divergence of its leaves will diminish. Finally, this divergence ought likewise to decrease some hours after sunset, when, by the fall of the dew, the air becomes relatively less a conductor.

Thus the daily variations which the electrometer exhibits in its indications appear to us to explain in part the changes which the electric radiation of this instrument undergoes in the course of the day. In the same manner we account for many observations made by De Saussure and other scientists. It is known that De Saussure found the intensity of positive electricity under a clear sky stronger onquays, and particularly on bridges, than in the open country. This ought evidently to be the case, not because the vapors which rise constantly from the surface of the water convey to the air a greater quantity of positive electricity, as has been supposed, but because the air, being in these places more saturated with moisture than elsewhere, ought to possess greater conductibility, and consequently render easier the electric radiation of the electrometer. In the same manner may be explained why the electric intensity is more feeble in summer than in winter, since, in summer the air being less moist than in winter, would also be less a conductor of electricity. We see, also, why in the times of prolonged drought the intensity of the electric periods decrease gradually, as has been observed by Schübler.*

* Journal de Schweigger, tom. VIII, p. 28.

But it is not necessary to conclude from what has been said that it is in radiation only that the cause of the daily variations of atmospheric electricity is found. We shall see, in speaking of the formation of electric clouds, that the sum of the facts tends to prove that the vapors reach the air charged with negative electricity, and that it weakens by its presence the higher positive influence to which the instruments are subjected, so that the indication of the electrometer must still decrease in the course of the day proportionally to the quantity of the vapor which rises in the air. But to appreciate the effect produced by this latter cause it is necessary to render the observations independent of the electric radiation of the instrument.

It has been remarked that a certain relation might be observed between the variations of atmospheric electricity and the other phenomena which take place periodically on the surface of the earth. For example, according to Mr. Kaemtz,* these variations are not perhaps without relation to the phenomena which accompany vegetation. It is known that, under the influence of solar light, plants give out oxygen, and that during the night they exhale carbonic acid. The former of these two opposite phenomena would be the most active when the sun is nearest the zenith, and the latter when this body approaches the horizon. Mr. Kaemtz thought that these two different modes, in which the plants acted on the air, could not be without some other influence on the daily variations of the electricity. But if we admit this opinion we must prove that the electric phenomena observed by M. Pouillet in his experiments on vegetation are, in fact, produced by the cause which this philosopher assigned to them.

Schübler thought he observed a correspondence between the oscillations of the magnetic needle and the electric periods.† The point of a horizontal magnetic needle turned to the north in fact moves from the east to the west, from eight and a half o'clock in the morning till one hour and a quarter after noon, and from west to east from one and a quarter hour in the afternoon till the next day morning. There is then a *maximum* of departure to the east, which takes place at eight and a half o'clock in the morning, and another to the west towards one and a quarter o'clock. Finally the same philosopher‡ made the observation that the daily variations of atmospheric electricity correspond very well with those of the barometer, the *maxima* also taking place for the latter as well as for electricity later in winter than in summer.

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* Lehrbuch der Meteorologie, tom. II., p. 411.
† Journal de Physique, tom. LXXV. p. 177. 1812.
‡ Journal de Schweigger, tom. III, p. 126.

CHAPTER III.

OF ATMOSPHERIC ELECTRICITY IN OVERCAST, FOGGY, AND CLOUDY WEATHER.

§ I.—*Of atmospheric electricity in cloudy weather and during fogs.*

De Saussure* appears to be the first who observed that in cloudy weather, but without rain or storm, atmospheric electricity exhibited almost the same character that it did in clear weather. The observations made by Schübler† confirm this result. The latter established the fact that when the weather was cloudy, without being at the same time stormy, the electricity was still positive; but he found that its intensity was less than in clear weather, as Cavallo‡ and other philosophers had already remarked before him. Further, the indications of the electrometer are stronger in winter than in summer; and although the daily variations may be less regular than in clear weather, they nevertheless present a period in the means of the observations made during the hours which are relative to the *maxima* and *minima* of every month. This is shown by the following table which gives the results of the observations that Schübler made under an overcast sky four times a day:

Months.	Mean monthly forces of atmospheric electricity.								Mean monthly force.	Mean monthly temperature.
	Hours.	1st minimum.	Hours.	1st maximum.	Hours.	2d minimum.	Hours.	2d maximum.		
		°		°		°		°	°	°
June, 1811	4 to 5	+ 3.40	7½ to 6	+ 8.20	2	+ 3.83	10	+ 7.33	+ 5.69	+15.8R.
July, 1811	5	4.00	6½	6.75	....	4.00	9½	7.00	5.43	16.6
August, 1811	5	5.00	7½	8.33	....	4.66	8½	10.00	6.99	14.3
September, 1811	7	5.50	8	8.00	....	3.50	8	9.00	6.50	11.3
October, 1811	7	5.20	8½	8.12	....	4.83	7½	8.00	6.53	11.3
November, 1811	7	6.00	9	7.86	....	8.50	7	10.66	8.00	5.1
December, 1811	8	8.93	10	12.00	....	15.31	6	19.41	13.91	1.5
January, 1812	7	9.76	10	14.00	....	16.86	6	25.64	16.56	— 2.4
February, 1812	7	6.60	9	9.60	....	8.50	7	13.10	9.45	+ 3.0
March, 1812	6½	3.00	8½	6.16	....	3.83	7½	7.40	5.09	3.8
April, 1812	6	3.00	8	6.50	....	3.50	8½	5.50	4.62	4.3
May, 1812	5	3 50	7	6.09	....	4.50	9	5.80	4.95	11.1
Means	....	+ 5.32	....	+ 8.46	....	+ 6.81	....	+ 10.7	+ 7.81	+ 7.9

The comparison of this table with that given on page 328 shows that the intensity of atmospheric electricity indicated by the electrometer is, in fact, less with a cloudy sky than with a clear one. But Schübler§ frequently observed that it was much stronger than ordinary in clear weather, and when, after a cloudy season, the sky suddenly became clear, the hygrometer indicated also considerable moisture in the air.

If a cloudy sky produced a decrease in atmospheric electricity, without, however, entirely concealing the daily variations, it was not

* Voyages dans les Alpes, tom. II, § 201, p. 221.

† Journal de Schweigger, tom. VIII, p. 21.

‡ Traité Complet d'Electricité, p. 293.

§ Journal de Schweigger, tom. VIII, p. 28. This increase in the intensity of the atmospheric electricity when the sky suddenly cleared up had been already noticed by *Beccaria.*

the same when fogs obscured the air. The latter, on the contrary, appeared by their presence to increase the positive tension of the apparatus, as nearly all have remarked who have made observations on atmospheric electricity. It was in thick fogs which did not terminate in rain that Th. Ronayne,* in Ireland, and Achard,† at Berlin, observed the strongest electricity. The latter of these scientists twice noticed that the divergence of the balls of Canton's electrometer ceased when the fog fell in the form of very fine rain, and wholly disappeared in less than a quarter of an hour. This phenomenon has some connexion, perhaps, with the fact, frequently observed, that the electricity of fogs sometimes changes from positive to negative when they are resolved into rain.

Volta‡ and De Saussure§ have both noticed the great tension of electricity during fogs; according to the former it was especially fogs attended by an odor which exhibited the most powerful action on the instruments; in this case, also, he frequently saw his electrometer exhibit a divergence which reached 100°, and sometimes gave out sparks at the approach of a conducting body. Schübler's|| observations also agree with those which we have mentioned, but the latter remarked besides that, during fogs, the variations of atmospheric electricity were wholly irregular, though its force varied with the seasons, as it occurred in clear weather, the electrometer presenting the greatest divergence in the winter months during the coldest days. The following table gives the mean force of this electricity for every month in the year:

Months.	Electricity during fogs.	
	Mean monthly force.	Monthly maximum.
June, 1811	+ 16°.0	+ 20°.0
July, 1811	------	------
August, 1811	+ 25.0	+ 30.0
September, 1811	20.5	25.0
October, 1811	18.0	30.0
November, 1811	18.1	28.0
December, 1811	32.7	36.0
January, 1812	34.1	44.0
February, 1812	32.2	55.0
March, 1812	21.0	21.0
April, 1812	15.5	17.0
May, 1812	14.0	14.0
Means	+ 22.5	------

Fogs sometimes exercise a negative action on the instruments; but fogs which produce this effect are less common. In speaking of the formation of electrical clouds, we shall see on what principle the frequency of positive fogs is explained.

* Philosoph. Transactions, vol. LXII, p. 140. 1772.
† Nouv. Mém. de l'Acad. de Berlin for 1780, p. 17.
‡ Dictionn. de Gehler, tom. VI, p. 484.
§ Voyages dans les Alpes, tom. II, § 801, p. 221.
|| Journal de Schweigger, tom. VIII, pp. 27, 31.

§ II.—*Of the electricity of the clouds.*

When the sky is cloudy without being overcast the instruments indicate numerous and irregular variations, either in the nature or in the intensity of the electricity. Nearly at the same period, Franklin,* in America, and Canton,† in England, first observed that among clouds some were in a positive others in a negative state. This fact was confirmed subsequently by all other observers. Frequently the electric tension was increased in the apparatus when a cloud approached the zenith, and the phenomenon was the more decided when the cloud, after being rapidly formed, was dissipated slowly.

Science possesses few data relative to the electricity of the clouds. According to observations of De Saussure‡ during his sojourn on the Col. de Geant, the electricity of the clouds on the peak of Mount Blanc was found to be constantly positive. Schübler,§ who examined the electricity of the clouds in the region of the air where they are formed, there discovered a force equal to what he was accustomed to find possessed by thick fogs in the low countries, and he obtained no signs of negative electricity except where the rain was formed. We will quote here some of his observations made in an ascent of the Rigi, 5,276 feet above the level of the sea.

Dates.	Degrees of the electrometer.	Observations.
July 10, 1813, 4 o'clock in the evening ----	— 120	The rain continues, and the observer is enveloped in the clouds.
4. 4----do------do--------	— 130	More powerful rain.
4. 30---do------do--------	— 120	Less powerful rain.
5------do------do--------	— 10	Rain ceases.
6------do------do--------	— 10	Clouds some hundreds of feet higher positively electrified. This electricity varies from 10 to 30 degrees.
8------do------do--------	— 110	Rain recommences.
9------do------do--------	— 150	More powerful rain.
July 11, 1813, 6 o'clock in the morning ---	— 140	Rain continues.
6. 4----do------do--------	— 140	Rain and thick clouds.
6. 12---do------do--------	— 135	Do.
6. 20---do------do--------	— 150	Do.
6. 28---do------do--------	— 130	Wind and rain.
7. 52---do------do--------	— 200	Rain more powerful.
9. 20---do------do--------	— 110	Rain less powerful.
10-----do------do--------	— 200	Rain more powerful.
1. 20 o'clock in the evening--	— 160	Rain a little less so.
1. 40---do------do--------	— 0	Rain has ceased.
2------do------do--------	— 4	The electricity of the clouds has become positive.

* Experiments and Observations on Electricity, pages 112, 114, and 129.
† Philos. Trans., vol. XLVIII. 1st part, page 356. 1753.
‡ Voyages dans les Alpes, tom. IV, § 2071, page 282.
§ Journal de Schweigger, tom. IX, page 354.

It follows, from observations made by M. Peltier,* that during the course of the summer of the year 1835 the greater part of the clouds were electric, and that nearly all of them possessed positive electricity. He found scarcely ten to twelve negative clouds among those which passed over his apparatus; but the case was entirely different in the summer months of the next year, during which M. Peltier continued his observations. The clouds were for the most part neutral, and even among those which he judged were electric, from their ashy color and their jagged and movable edges, most of them left the instruments in complete repose. Those which were electric were nearly all negatively so.

The only inference which can be drawn from the preceding is, that positive clouds are greater in number than negative ones.

§ III.—*Of the formation of electric clouds.*

The formation of electric clouds is a question the solution of which has occupied many philosophers. Some of them, and at their head the illustrious Volta,† have sought to explain it by admitting, as we have already seen, that the positive electricity rises in the latent state with the vapor furnished by the ground, and becomes free again when it is condensed. Such might be the origin of clouds positively electrified as well as of atmospheric electricity. As to the formation of the negative clouds, Volta thought that a cloud strongly positive must exercise an electrical influence on a very feebly electrified cloud lying within its sphere of activity, and consequently produces a decomposition of its natural electricities; so that if the repelled electricity meets other clouds, vapors or eminences on the surface of the earth, it will escape and leave the cloud charged with negative electricity. By means of this theory we may explain in a satisfactory manner the strong positive electricity which is observed during fogs and dew, and especially that which is exhibited in the rapid formation of thunder clouds; but we have seen that the facts which science possesses in its present state do not favor this theory.

De Saussure‡ has advanced the opinion that the clouds perform no other office than that of a conductor, and that the electricity which is perceived at the moment of their passage above an electro-atmospheric apparatus is only that which they derive from the higher strata of the air. He was led to this result by an experiment made on the top of Fours, in which he observed that, in throwing into the air during the absence of clouds the small leaden ball of his electrometer, he obtained an electricity equal and even superior to that which those clouds gave in passing above his head.

M. Gay Lussac§ supposes that the electricity is disseminated in the atmosphere, in a free state, ready to be transferred to the conductors which are presented to it, and that it exists in the same quan-

* Comptes Rendus, tom. III, page 145. 1836.
† Journal de Physique, tom. XXIII, page 99, 1785.
‡ Voyages dans les Alpes, tom. II, § 783 and 786, page 194 and 198.
§ Ann. de Chimie et de Physique, tom. VIII, page 167.

tity in the cloud just formed as in the mass of the air before the formation of the cloud. "If," says he, "a cloud is formed while the air is pure and transparent, and the electricity is thus disseminated in all its mass, every vesicle being a good conductor, the electricty will unite at its surface in a stratum extremely thin, and may remain in this state, if it is weak and if the aqueous vesicles are not near each other. We shall thus have a cloud which in this state will not be stormy; its electricity will be the same as that of the mass of air in which it is formed, but its tension will be increased by its less diffusion and its concentration around the vesicles. The cloud must then appear more strongly electrified than the transparent air, as observation demonstrates. If the cloud is very dense, and consequently the vesicles which form it are much closer, it may be regarded as a continuous conductor; and according to the laws of electric distribution the fluid will abandon the interior of the cloud for its surface, on which it will diffuse itself in equilibrium, and will be there retained by the pressure of the surrounding air."

M. Gay Lussac thinks that the electricity usually diffused in the air and collected in this manner is sufficient to render clouds powerfully electrical.

In this way of considering the formation of electric clouds, M. Gay Lussac makes no mention of the nature of the electricity which is transferred to their surface when they are very dense; it must be necessarily admitted that it is positive, since the atmosphere in clear weather always possesses positive electricity. We might, indeed, thus explain the formation of clouds charged with positive electricity; but how cou d we conceive the existence of clouds negatively electrified, when the atmosphere in which they are formed contains only positive electricity. M. Lamé* thus explains this phenomenon. "The clouds occupying different heights, and experience indicating that atmospheric electricity observed in clear weather is greater at greater distances from the surface of the earth, it is conceived that the higher clouds, charged with a greater quantity of positive electricity than those below, may act by induction on the latter, repelling their positive fluid, which being dissipated more quickly in the air than the fluid attracted, leaves the negative electricity free on the lower clouds." But if it is we admit that electric clouds exercise on each other an action by induction, still it is not seen how the positive fluid repelled should dissipate itself sooner in the air than the fluid attracted; ought not the contrary rather to take place on account of the less distance which separates the upper cloud from the portion of the lower cloud where the negative electricity attracted may be accumulated?

M. Becquerel† proposed a new theory of the formation of electric clouds, which embraces at once positive, negative, and neutral clouds. According to this philosopher, the vapor which is formed on the surface of the globe in general carry with it, besides the positive electricity which is peculiar to it, a portion greater or less of the negative electricity which the earth habitually possesses. "Hence,"

* Cours de Physique de Ecole Polytechnique, tom II, 2d part, page 80. Paris, 1837.
† Traité de l'Electricité et du Magnétisme, tom IV, p. 121.

he says, "according to the tension of this electricity, the vapor which rises in the air is electrified positively, negatively, or is found to be in a neutral state, and the clouds to the formation of which it concurs partake of the same electrical state. We cannot determine," he adds, "in what circumstances the vapor is negative, since the tension of the electricity of the earth must vary on account of the nature of the portion of surface where the evaporation takes place. If the liquid which forms the vapor rests on conducting bodies, the negative electricity diffuses itself at a distance; while, if they are bad conductors, it remains in its place, and in this case perhaps it is borne off by the vapor and unites in the formation of negative clouds."

This theory of M. Becquerel is based on the hypothesis that the water receives positive electricity by being transformed into vapor, and that the same vapor, in certain circumstances, carry off a greater or less portion of the negative electricity of the ground. The first part of this theory is at variance with the experiments of M. Peltier. The second M. Becquerel sought to sustain by observation of the negative electricity of cascades. We are indebted to Tralles* for the first observation of this phenomenon. Finding himself one day in the Alps, opposite the cascade of Standbach, (Staubbach?) near the Sauterbrunnen, he presented his atmospheric electrometer, not armed with the metallic wire, to the fine spray, which resulted from the dispersion of the water. He immediately obtained very distinct signs of negative electricity. The same effect was exhibited at the cascade of Reichenbach. Volta, a short time after, verified the correctness of this observation not only above the great cascades, but also wherever a fall of water existed, however small provided the intervention of the the wind, caused the dispersion of the drops. The electricity always appeared to him as it did to Tralles, negative. Schübler† repeated the same experiments in his journey to the Alps, in 1813. He observed farther, that this negative electricity was very strong, since it became perceptible at a distance of 300 feet from the cascade of Reichenbach, and at a distance of 100 feet his electrometer indicated 400, and even 500 degrees. On presenting to the spray a small Leyden phial, armed with a point furnished with ignited tinder, it became charged in a few moments, so as to furnish sparks and sensible shocks—a phenomenon which Schübler did not observe, except in rains, strongly electrified, and during storms. During these experiments the sky was clouds.

The negative electricity found in the dispersion of water has been explained in different ways. Tralles attributed it at first to the friction of the minute drops of water against the air; but soon after he thought with Volta, that the cause was to be found in the evaporation which the same minute drops experience in falling. It may be said, as to the first manner of interpreting this phenomenon, that if experience shows that the parts of a solid body, like charcoal, reduced to fine

* Oeuvres de Volta, tom. II, page 239.

† Journal de Schweigger, tom. IX, page 358.

powder, acquire by their friction an electricity perceptible by the electroscope, there is nothing to show that the same will not be the case even from the friction of the liquid particles against each other, or of the liquid particles against the particles of air. Besides, an electricity as strong as that which is exhibited by the spray of the cascades would be scarcely in proportion to so feeble a cause of development. As for the second explanation, which is the one given by Volta, and which Schübler also adopted, besides that it rests on the hypothesis of the development of the electricity, in the formation of vapor, a number of other objections may be made, to which it is difficult to give a satisfactory answer. Thus it appears impossible to conceive how the drops of water in simply falling from the height of some hundred feet can become electrified by evaporation, so as to produce an electricity as strong as that which has been observed during storms, and even stronger than that which is ordinarily exhibited in the drops of rain which fall from a height incomparably greater.

As we have already said, M. Becquerel found in the negative electricity of falls of water a proof of his theory of the formation of negative clouds. According to him, this electricity proceeds from that which the earth habitually possesses. The water, in falling with great velocity on the rocks, is scattered into vesicular globules, which carry with them into the atmosphere the negative electricity which they have taken from the rocks. M. Becquerel drew from this the conclusion that the vapor which is formed at the surface of the globe may, in the same way, carry away a portion of the negative electricity of the earth.

This explanation has been opposed by M. Belli,* who believes that the electrical phenomenon of the water of cascades is owing to the development of electricity by the induction which the positive electricity of the atmosphere exercises on the water. "The water," he says, "is by induction in the negative state, when the atmosphere is as it is ordinarily, charged with positive electricity. At the moment when this water divides into thousands of minute drops, it cannot fail to carry the electricity with which the electrical induction of the atmosphere has impregnated it to all the bodies which it meets." M. Belli made some experimental researches in support of his opinion. He arranged in an uncovered place, and under a clear sky, a portable fountain. He then discharged a jet of water slightly inclined from the perpendicular, and collected the drops which escaped in an insulated vessel, communicating with a Leyden phial. On examining it with the condenser, he ascertained that the drops of water were very perceptibly negatively electrified. When the compressed fountain was insulated and put in communication with an electroscope, he obtained a very marked divergence of positive electricity, which was reproduced every time it was destroyed by momentarily touching with the hand the ball of the electroscope. According to M. Belli, these experiments demonstrate that the column of ascending water becomes electrified by the electric induction of the atmosphere. To show that the evaporation of the water was of some importance in this phenomenon, he repeated

* Bibl. Univ., Nouvelle Serie, tom. VI, page 148. 1836.

the same experiments in one of the courts of a large building, without any electrical sign appearing, which accords with the theory since we know, from De Saussure's experiments, that the electric induction of the clear atmosphere is not felt in a sensible manner in places inclosed on all sides.

This last explanation indicates the true cause of the negative electricity of the water of cascades, since the divergence of the gold leaves of an electrometer exposed to the air proves that the induction of the positive electricity of the atmosphere is felt at the surface of the earth, while experiment demonstrates that it is in an habitual state of negative electricity. We may remark that this explanation is susceptible of proof of another kind; for if it be true, the electricity of the water of the cascades will not always have the same sign; it will be negative if the atmosphere is positive; on the contrary, it will be positive when the clouds are negative. In order, then, that there may remain no doubt as to the cause of this phenomenon, it would be sufficient to examine the electricity of natural cascades in stormy weather.

Although the explanation of M. Belli differs sensibly from that which M. Becquerel has given, yet it goes to support the cause assigned by the latter philosopher for the formation of negative clouds. If the water at the moment of the evaporation is negatively electrified by the influence of atmospheric electricity, the vapor must necessarily partake of that electric state and carry away with it a portion of the negative electricity. This vapor, then, in passing to the vesicular state will constitute clouds negatively electrified. But, as we have already observed, if the theory of M. Becquerel explains the formation of negative clouds, it gives an explanation of positive clouds which the present state of the science cannot allow us any longer to admit.

M. Peltier, in his new theory of the electrical phenomena of the atmosphere,* considers the formation of electric clouds in a way which appears more in harmony with observed facts. He remarks that the atmosphere is the seat of two kinds of evaporation, one of which is produced at the surface of water and of moist ground, and the other at different heights in the air, when the opaque clouds pass to a state of elastic vapor. The former, when the sky is serene, cannot generate positive vapors, since experiment shows that when vapor is produced at the ordinary temperature the electrometer exhibits no sensible trace of the electricities disengaged at the instant of its formation; but as this vapor is formed at the surface of the earth, which possesses a great negative tension, and under the positive influence of the sky, it must necessarily be charged with negative electricity. M. Peltier sought to verify this by the experiment of placing the water in the same conditions as it is found in nature, that is to say, under a positive influence; the vapor disengaged from water, distilled or not distilled, contained in an insulated vessel and placed under a globe positively electrified, was found to be negative, while the remainder of the liquid remained positively electrified.

* Comptes Rendus, tom. XII, page 307, and Annales de Chimie et de Physique, 3d series, tom. IV, page 414, &c.

After having established this principle, M. Peltier thus explains the electricity of clouds: When the first elastic vapor charged with negative electricity has been condensed into opaque clouds by being cooled down, and the temperature in rising again afterwards produces a second evaporation, which takes place under a superior positive induction, and the first vapor produced has its negative tension increased, at the expense of the lower strata of cloud, kept at the positive state by terrestrial influence. It follows that the elastic vapor produced in the second evaporation is more strongly negative than that first formed, while the vapor produced by the evaporation of the lower strata of the cloud will become positive. When a new lowering of temperature afterwards produces condensation into clouds of the secondary vapor, the higher masses form negative and the lower masses positive clouds, the former keeping themselves at a greater elevation than corresponds to their specific gravity, because of the repulsion of the earth, the latter, on the contrary, descending to a lower level than belongs to their weight on account of the attraction of the globe. This transformation of the elastic into opaque vapor, and of opaque into elastic vapor, alternating a great number of times, according to the atmospheric conditions, would result in clouds the electric tension of which may become very powerful. M. Peltier produced an illustration of one of these transformations by making use of a considerable number of very small soap bubbles, which he subjected, in an insulated capsule of glass, to the positive action of a globe; he saw some of these balls elongate, shoot out, dissolve, and disappear, leaving the rest of the cloud powerfully charged with positive electricity, a phenomenon which indicated that all the parts which rushed out and were dissolved were negative.

It appears, also, according to the same philosopher, that observations may be made in support of this theory when the sky is sprinkled with cumuli, thin enough to distinguish their interior movements. In examining one of these thin clouds, we see that each of its parts changes its position in relation to the others while the evaporation is going on; and these movements are the more extended the more rapidly the evaporation proceeds, without, however, being the same in the whole mass. Toward the edge which receives the direct rays of the sun, the evaporation being greater, the opaque vapor becomes strongly positive, and we see it attracted towards the earth, pass below the mass of cloud, and continue there while on the opposite side the vapor extends and disperses until it is all transformed into elastic vapor, but without the great agitation or lively repulsion from above to below. Finally; after a succession of of warm days, which reproduced a series of transformations of the opaque into elastic vapors, and *vice versa*, we may sometimes, by means of the kite, reach some of those masses of elastic vapors having an electric tension different from that of the adjacent masses, and strong enough to neutralize the whole positive current produced in the lower strata.

This explanation of the electricity of the clouds admits that the vapor enters the air charged with negative electricity. The detail into which we have entered, and the observations on the elec-

tricity of cascades of water, appear to leave no doubt as to this fact. On account of the electric repulsion of the globe, and the superior positive induction to which the vapor from the surface remains subjected, it preserves its negative state though the first strata of the air in which it is diffused are generally already very humid and consequently conductors of electricity; but the presence of this negative vapor in the air weakens the superior positive, and thus, as M. Peltier remarks, the indication of the electrometer would decrease in the course of the day in proportion to the quantity of the vapor which is eliminated under the contrary tensions of the earth and of space. Such might also be the cause of the daily variations of this instrument if its indications were wholly independent of its electric radiation, and consequently of the conductibility of the air. The primitive vapor while undergoing the commencement of condensation produces at first clouds possessing a feeble negative electricity. According to M. Peltier, these are then subjected to a double electric influence; the one positive, produced by the celestial space, the other negative and produced by the earth; and as it is under this double influence that the new evaporation takes place, this evidently will produce at first negative vapor, and afterwards positive vapor, which, in its turn, forms clouds possessing electricity of the same kind. But would not the same thing happen supposing the air to be provided with positive electricity, the intensity of which might vary with the height? In this case the cloud might experience the induction of the positive electricity of the strata of the air which are above it, and at the same time that of the electricity of the air situated below it; on account of the increase of the electric intensity with the height, the first action may be stronger than the second, and supposing the cloud negatively electrified at first, there would also result an accumulation of the negative electricity in its higher strata, while the positive electricity produced by a new decomposition of the natural electricities of the same cloud would be restored in a great measure in its lower strata. In this way the first elastic vapor, produced by a new evaporation, might still be negative, while that which had been last formed might equally become positive. Only if it be admitted that the molecules of the air have a positive electricity which is peculiar to themselves, it will happen that the negative electricity of the primitive vapor may re-combine, in part or in whole, with the positive electricity of the molecules of the air, consequently the cloud formed by their condensation will be found to be positively as well as negatively electrified, or rather be in a neutral state. In every case the first elastic vapor, owing to a new evaporation of this cloud, will be found in a negative state, in consequence of the positive influence of the higher regions of the air. This mode of regarding the formation of the electric clouds explains also the frequency of the fogs with which the lower strata containing positive electricity are charged. As for the negative fogs, M. Peltier thought that they are retained in contact with the earth only in consequence of their specific gravity, which prevails over the electric repulsion of the earth, or by the repulsive force due to a current of negative vapor which, according to the same philosopher, travels from the equator to the pole.

§ IV. *Of the distribution of electricity in the clouds.*

Experiment shows that electricity is conveyed to the surface of conducting bodies, and that it exhibits no trace of itself in their interior. We may ask if it is the same with respect to clouds. Ought we to regard the mass of vesicles which form a cloud as a single body, on the surface of which all the electricity is distributed, or rather ought we to admit that during the formation of a cloud each vesicle preserves, in whole or in part, its atmosphere of electricity? We are already acquainted with the opinion advanced by M. Gay Lussac on this subject; he supposed that the clouds which exhibit certain density are similar to ordinary conductors and that the electricity is simply conveyed to their surface. M. Kaemtz* does not concur in this opinion. In fact, if it were so, it would be difficult to explain how the clouds can contain so great a quantity of electricity, as that which is observed in storms; how in this case the electricity does not neutralize itself by a single explosion, or at least by a small number of explosions; and finally, how the charges of electricity ane reproduce so numerously and so close to each other. Besides, the explosions ought to cease with the first rain, since the communication which this establishes between the cloud and the earth ought to allow the electricity to escape freely. It appears more probable to M. Kaemtz that every vesicle, whether it enters into the composition of a thunder-cloud or not, preserves a portion of its electricity, and that this portion is greater the nearer the vesicle is situated to the surface of the cloud. As to the cause which might thus retain the electricity around each vesicle, M. Kaemtz found it in the resistance which the electricity must experience in passing from one vesicle to another, a resistance which is due to the imperfect conductibility of the air interposed. This mode of considering the distribution of the electricity in the clouds does not explain how the vesicles of vapor, electrified in the same manner, form masses as limited as the clouds are, instead of diffusing themselves uniformly by their mutual repulsion.

M. Peltier † also regards the vesicles of vapor of which clouds are composed as surrounded by an electric stratum. "A cloud," says he, "is properly not a body such as is usually understood by this word; it is not a whole of which the particles are compacted as those of solid bodies, nor even those of liquids by their adherence or proximity. Held together with little force the particles of clouds do not readily permit the propagation of electricity; the spaces which separate them maintain their isolation and their independence, and it is only in their condensation, from whatever cause, that their masses resemble in some slight degree ordinary bodies, and readily transmit electrical changes. If these particles are widely separated, and have consequently preserved a great independence, they each retain all their electric energy, the whole tension which they have acquired, and the mass of vapor will act with a power propor-

* Lehrbuch der Meteorologie, tom. II, page 414.
† Comptes Rendus, tom. X., pages 202 et 841. 1840.

tional to the sum of the partial forces, without there being any remarkable discharges. It will produce only the effects of static electricity, those of attraction or repulsion, and those of simple radiation. If, on the contrary, the particles of vapor are sufficiently near for their electric spheres to penetrate each other, or if the repulsion of the electrical spheres act more strongly than the bond which unites them to the vapor, all the internal particles will lose a portion of their electricity in favor of the extreme particles; there will then be formed around the exterior of the cloudy mass a stratum of free electricity such as is usually formed around an ordinary conductor."

Thus, according to M. Peltier, the clouds have two kinds of tension; the tension of free electricity at the surface, and that of the electricity retained around each of the moleculs of its vapor. From this M. Peltier sought to explain how vapor could form limited masses, notwithstanding the mutual repulsion of the particles, owing to the electric tension of the latter. The tension of the particles repels them and keeps them at a distance, while the electricity of the surface attracts them, groups them, and retains them in mass, everywhere leaving to each its individuality, if the exterior tension is moderate and proportional to that of the interior. M. Peltier has demonstrated this repulsive and condensing action from the exterior to the interior, by the following experiment: He isolated a glass funnel, the tube of which was one or two millimeters in diameter, and filled it with water, communicating by means of a conductor with an electric machine. By allowing the water to escape under the influence of the electricity furnished by the latter it falls, as we know in rain more or less fine, according to the electric charge which is given to it. But if a copper tube of the height of 5 to ten centimetres and of a diameter nearly equal be placed a little below the orifice of escape, and if it be charged with the same electricity as the water, instantly the drops of the latter will approach and unite together in a single stream. This experiment is rendered more complete by making use of a metallic insulated globe, the diameter of which is pierced with two holes to let in a ray of light. The water of the funnel being electrified falls into the globe in a divergent cone. The globe gradually becomes electrified and reacts on the streams which approach and unite until there is an equilibrium of reaction between the interior repulsion and that of the exterior. If the globe communicates with the electrical machine, the powerful tension immediately reunites the divergent streams into a single one as in the experiment of the tube.

The electricity which surrounds a cloud could not therefore be formed of all the electricity which it contains, as that of a metal conductor which retains no portion in its interior; it would be, on the contrary, only a feeble portion dependent on interior reaction and conductibility. This theory simplifies and facilitates the interpretation of many phenomena which take place during storms; it would be important to see it confirmed by direct observations, which might be possible by studying, especially in mountainous countries with the help of kites sustained by conducting wires, the electrical modifications of the different parts of a cloud. M. Peltier* found in the two kinds of elec-

* Journal l'Institut, No. 335 and No. 370.

trical tension existing in the clouds the cause of the different forms which these bodies assume. "At first," remarks he, "every vesicle preserves an electric atmosphere like an independent and insulated body; then if all the reactions which follow have been in every respect equal, the vapor should be uniformly diffused; but it is sufficient that there are inequalities in the density of the vapor, in order that there should be inequality in the electrical reactions. The more powerful tensions distributed in the different points react by repulsion on the internal vapor; they condense it, limit it more decidedly, and form the first cloudy flakes. These, acting together as elementary vesicles, form by their unison masses more complex, called fleeces, separated by intervening clear spaces with jagged edges. Each of these fleeces is surrounded by its own electrical sphere, which reacts on the flakes and passes them together as the sphere of flakes reacted on the elementary vesicles. These fleeces, regarded as elements, produce in their turn *strata* or clouds, properly so called, and then afterwards form the *cumuli* of different orders." The formation of the *cirri* reveals also, according to M. Peltier, another electrical cause, namely, the attractive action of two masses of vapors or of two separate bodies possessing different electricities. The vapors interposed and attracted in the longitudinal direction are formed in a line, while their unequal density in the vertical direction, permitting an unequal distribution of electricity, there result lateral repulsions producing, fibrous condensations of vapors which constitute the *cirri*. This last effect may be reproduced experimentally by substituting for the vapor small pieces of gold leaf placed between bodies charged with opposite electricities. These pieces of gold leaf are formed into line between the two bodies and constitute threadlike conductors. M. Peltier relates that he likewise reproduced a part of this phenomenon with clouds formed of small soap bubbles.

CHAPTER IV.

OF ATMOSPHERIC ELECTRICITY DURING RAIN, SNOW, AND STORMS.

§ 1.—*Of atmospheric electricity during rain and snow.*

When a cloud resolves itself into rain, every drop of water conveys to the electrometer its electric atmosphere, and this attains an electric tension which is sometimes very considerable. Observers are not all agreed respecting the changes which the electricity of this instrument indicates, during the fall of rain. Thus, according to Volta,* the positive electricity increases on the approach of the cloud, and decrease afterwards with the fall of the first drops of water, becomes nothing, and finally passes to a very strong negative state. This electricity preserves its intensity during half or an entire hour; but if the rain continues a longer time it decreases and becomes very feeble; only it

* Lehrbuch der Meteorologie von Kaemtz, tom. II, p 413.

receives a new addition, every time that the rain increases a few moments. It would follow, then, from this that rain should, in general, be negative. According to the English philosopher Foggo,* the electricity, on the contrary, is positive as long as the cloud which pours out the rain is at a distance from the zenith of the conductor, and it only becomes negative when the anterior part of the cloud is above the conductor. This state then continues during a short space of time; after which positive electricity appears anew, and continues while the cloud is passing over the conductor, to which again succeeds positive electricity. M. Kaemtz states that he has frequently observed positive electricity during rains of short duration.

We owe to Schübler† two regular series of observations relating especially to the electricity which is exhibited during the fall of rain and of snow, and which were made, the former at Ellwangen, from January, 1805, to the month of April, 1806, and the latter at Stuttgard, from June, 1810, to the month of August of the following year. In the space of two years and a half Schübler observed the electricity of 412 falls of rain, snow, &c. According to these observations, it is rare that there is rain without electricity; the phenomenon has not been noticed, except when the electricity of a rain changes from plus to minus, or the reverse; then the electricity ceases for several seconds. The electricity is again at zero at the commencement, or at the end of a negative rain, as well as at the period of the passage of ordinary positive electricity to that of an equally positive rain, and finally during a very feeble rain. When the rain falls in a regular and uniform manner, which is frequently the case, electricity remains for whole days negative or positive; it varies simply in its intensity, which is generally in proportion to the quantity of water which has fallen.‡ It is not the same when it rains in an irregular and disconnected manner; the electromoter then exhibits oscillations; the straws diverge, fall back, and their divergence is sometimes positive, sometimes negative. Schübler remarked that the changes of the sign in electricity corresponded to the difference either in the size of the drops of water or in their number. These facts are frequently observed when isolated waves succeed each other rapidly; we then frequently find the electricities positive and negative, successively, in the same degree of intensity. The electrical phenomena which accompany the fall of snow are not less complicated; just as in rain, at every change which happens, either in the form or size of the snow flakes, or in their number, there is a corresponding new electrical state. Schübler rendered these changes in the intensity and nature of electricity more evident by making, at very short intervals, successive series of observations, which he represented by curves, in which the abscissa expressed the time and the ordinates the corresponding intensity of the electricity in the degrees of the electrometer.

* Edinburgh Journal of Science, volume IV, p. 124.

† Journal de Schweigger, tom. XXV, p. 249, tom. VIII, p. 21, and tom. XI, p. 377. 1829, 1813 and 1814.

‡ This latter has also been established by Beccaria, *Lettere dell' Electricismo*, p. 307.

This relation between the fall of rain and the changes in the electrical state of the apparatus was observed by M. Arago* and M. Peltier.† Besides, the latter of these two philosophers noticed an electrical fact which preceded the sudden appearance of hoar-frost, and which tends to verify the opinion advanced by him as to the formation of this body, which he considered, as well as hail, accompanied by electrical discharges. He states that, before the hoar-frost falls, the needle of the rheometer of his apparatus may be seen to deviate a number of degrees, more or less considerable, then all at once retrograde rapidly and pass from the other side of the zero, as is the case during storms before a flash of lightning, and at the moment of its appearance. By means of these indications he ascertained that the approaching fall of small hailstones could be readily foretold.

The oscillations which are exhibited in the electric state of the electrometer, during the fall of rain or of snow, is particularly worthy of the attention of observers, since similar effects are produced in the electrical discharges during storms. We may ask, if the indication of this instrument is really produced by the electricity of the rain. Schübler's observations cannot decide this question. In fact they were made with Volta's electrometer, supplied with a conductor and an ignited body; now, when this instrument is exposed to the air during the fall of rain it is subjected at once to the influence of the electricity of the air, which is always positive, to that of the electricity of the cloud from which the rain falls, and which may be positive or negative; and finally to the electricity of the rain which strikes on it. The following observation of M. Peltier‡ may throw some light on this subject: "On the 8th of June," as this observer states, "toward four o'clock in the evening I had a descending current, the rain began about five o'clock. There were several negative and positive alternations in the direction of the current. The water which fell did not change its sign as the current did, it always gave negative indications to the electroscope."

To ascertain what in the indications of the electrometer is due to the electricity contained in the rain when it comes in contact with the ground, it is necessary to withdraw the instrument from the electrical influence of the clouds, as well as that of the air. Perhaps it may be ascertained by receiving the rain into an insulated metal vase, which may be made to communicate with an electrometer without by a stern placed in the inside of an apartment. It is well known that in this case the instrument is protected from the electrical influence of the air, as well as from that of the clouds.

We have already said that the electricity of the electrometer acquires during the fall of rain a tension superior to that of the clear sky. If we refer to the observations made by Schübler, at Stuttgardt, from 1811 to 1812, the intensity of the electricity of the rain and the snow presents an annual period, the stronger electricity taking place in the summer, the feebler in the winter. This is what is indicated in the following table, which gives the mean force of the two electricities for

* Traite de l'Electri. et du Magn., par Becquerel, tom. IV, p. 100.
† Comptes Rendus, tom. III, p. 145, 1836, and Le Journal l'Institut, No. 228, May 10, 1838.
‡ Comptes Rendus, tom. III, p. 145. 1836.

every month, as well as the number of days of rain or of snow during which the electricity was negative or positive.*

Months.	Mean force of electricity.		No. of days during which the electricity was positive.		No. of days in which the electricity was negative.		Quantity of water collected in inches.
	Positive.	Negative.	Rain.	Snow.	Rain.	Snow.	
	°	°					
June, 1811	+ 235	— 275	9	0	9	0	5.71
July, 1811	+ 400	— 280	5	0	5	0	1.05
August, 1811	+ 290	— 80	7	0	7	0	1.66
September, 1811	+ 30	— 10	1	0	2	0	0.70
October, 1811	+ 26	— 31	5	0	6	0	1.89
November, 1811	+ 24	— 25	2	1	3	0	0.84
December, 1811	+ 32	— 157	1	9	3	0	1.42
January, 1812	+ 40	— 173	0	7	1	2	1.06
February, 1812	+ 41	— 44	2	1	8	1	1.72
March, 1812	+ 74	— 65	6	2	8	3	1.61
April, 1812	+ 40	— 58	0	4	5	0	1.26
May, 1812	+ 186	— 179	9	0	6	0	2.14
Yearly	+ 118	— 114	47	24	63	6	21.06

We may add to this table the general remark that rains exhibit an electricity which is strong in proportion as they are abundant in a given time. This stronger electricity accompanies showers—always transient rains and storms.

We have seen above that Volta in general found that the electricity of the rain which he observed was negative. If in Schübler's observations, of which we have already given a summary, we recapitulate separately the number of days of rain or snow during which the electricity has been positive or negative, we find, on the contrary, 71 days positive and 69 negative, that is to say almost the same number of positive as negative days. The observations made by Hemmer,† at Mannheim, from 1783 to 1787, lead to the same result; he found these two numbers in the proportion of 1 to 1.08. According to the observations of M. Arago,‡ during the first seven months of 1830, there were eleven days of rain without electricity, six days with positive electricity, and eight days with negative electricity. From the collective result of these different observations, we

* To obtain the numbers contained in this table, Schübler noted separately the degrees of positive electricity and those of negative electricity. Where the electricities of different nature alternated, he added apart the degrees observed and corresponding to the rains or snows, positive as well as negative: and, if one of these two electricities preponderated, he kept a proportional account. When a rain or snow gave signs of only one electricity, but with a variable intensity, he placed it at the higher degree in the account. Finally, he did not measure the electric tension beyond 600 degrees of the straw electrometer; then the electricity began to give out sparks, and a small Leyden phial, which was charged with free air, gave quite powerful shocks.

† Lehrbuch der Meteorologie, von Kaemtz, tom. II, p. 418.

‡ Traité d'Electricité et du Magnet., par Becquerel, tom. IV, p. 100.

might conclude that the electricity of rain or snow is sometimes positive and sometimes negative, and this nearly for the same number of times. But we ought to observe that the two other series of observations by Schübler* do not exhibit the same result; of the 412 observations of which they are composed, the rain or snow was 161 times positive and 251 times negative, that is to say, in the proportion of 100 to 155. It would appear, even according to these observations, that the winds were not without influence on the kind of electricity with which the air was effected. In fact, in grouping the positive rains and the negative ones according to the directions of the winds, Schübler found the following results:

Winds.	Number of positive rains.	Number of negative rains.	Proportion.	Total number of rains.
North	12	11	1 : 0.91	25
Northeast	11	12	1 : 1.09	23
East	3	5	1 : 1.66	8
Southeast	4	7	1 : 1.75	11
South	5	13	1 : 2.60	18
Southwest	28	65	1 : 2.32	93
West	73	106	1 : 1.45	179
Northwest	25	32	1 : 1.28	57
Total	161	251	----------	412
For three winds—NW., N., and NE	48	55	1 : 1.14	103
Do. SE., S., and SW	37	85	1 : 2.30	122
Do. SW., W., and NW.	126	203	1 : 1.61	329
Do. NE., E., and SE	18	24	1 : 1.33	42

Taking for unity the number of positive rains, Hemmer found for the same winds the following proportions:

North	1 : 0.47
Northeast	1 : 0.84
East	1 : 0.91
Southeast	1 : 0.98
South	1 : 1.04
Southwest	1 : 1.10
West	1 : 1.08
Northwest	1 : 0.66

*Journal de Schweigger, tom. XXV, p. 254.

These observations concur in showing that the rains which fall while the north winds are prevalent are more frequently positively electrified than negatively, while the contrary is exhibited by the south winds. The *maximum* coincides with the north wind and the *minimum* with the S. or SW. wind.

Although in Schübler's observations, mentioned above, the proportion of the number of days of positive rain to that of days of negative rain was as 100 to 155, yet the mean force of the positive electricity was greater than that of the negative in the proportion of 69 to 43. This superiority of positive over negative electricity was observed in all the winds, as may be seen by the following table, in which the mean forces of the two electricities are given for each:

Winds.	MEAN FORCE OF ELECTRICITY.	
	Positive.	Negative.
	°	°
N	+ 131	— 99
N. E.	105	132
E	15	13
S. E.	19	10
S.	26	23
S. W.	66	33
W.	75	39
N. W.	31	46
	+ 69	— 43

We think we may pass in silence the explanation which Schübler gave of the different results to which his observations conducted him on the electricity of rain, since it rests on the hypothesis that the vapor at the moment of its formation receives positive electricity. Besides, it is evident that an explanation ought not be hazarded until these first observations shall be confirmed by new observations, in which the indications furnished by the instruments shall be more in accordance with the actual intensity of the electricity which is to be measured.

§ 2.—*Of atmospheric electricity during storms.*

Atmospheric electricity has its greatest tension in stormy weather, and is often so great that the instruments are insufficient to measure it. The currents are sometimes so intense that they demagnetize the needles of the rheometers, and tear in pieces the gold leaves of the electrometers.* This powerful tension is exhibited also by the flashes of lightning, the sparkling rain, and the luminous effects which appear at the extremities of conducting bodies.

These observations concur in showing that electricity undergoes frequent and sudden variations in its nature as well as in its intensity

* Comptes Rendus, tome III, page 147, and tome XIII, page 214. 1836 and 1841.

during the whole time a storm lasts. Volta,* who directed his attention to these variations, states that he observed as many as fourteen changes of sign in the space of one minute by exposing his electrometer to the action of thunder clouds; and, according to De Saussure,† these changes follow each other in some cases with such rapidity that we have not time to record them. Schübler‡ has also made some observations, which define these electric variations better than any one had done before him; they teach us that the electricity of the electrometer gradually increases in proportion as the storm draws near; that it reaches its maximum when the storm is nearest to the point of observation. Independently of these gradual changes, it also undergoes others, which are exhibited in a sudden manner at the moment of the appearance of every flash of lightning; finally, that this last phenomena produces, also, in the electricity a sudden passage from one state to another of an almost equal intensity. To study the course of the electricity during storms, Schübler made a series of observations at very close intervals of time, and he represented the result by a curve, as in his observations on the electricity of rain and snow.

To show how complicated are the electric phenomena, we here quote the details of observations made during two storms—one of which passed at a distance, the other appeared directly over the zenith of observation:

"*April* 11, 1806.—In the day the electricity of the air is feebly positive, and the temperature rose to 11° R.

"6 *o'clock, evening.*—It began to rain; the electricity became negative.

"7 *o'clock, evening.*—The rain ceased; dark cloud covers the sky, and a storm shows itself in the horizon on the southeast. The electricity is still negative; it decreases suddenly with the flashes of lightning, every one of them producing, in the straws of an electrometer, an approach, followed by a new divergence, but less than that which took place the moment before.

"7 *o'clock* 14 *minutes, evening.*—A flash of lightning suddenly reduces the electricity to zero, but causes it to pass for an instant to the positive state; it afterwards becomes negative.

"7 *o'clock* 18 *minutes, evening.*—The electricity becomes positive, and remains so from this instant till that in which the storm appears to be nearerest; the positive electricity goes on increasing; with every flash of lightning the straws diverge, to fall back almost immediately, yet preserving every time a greater divergence than what they before had.

"7 *o'clock* 45 *minutes, evening.*—The storm moves in the direction of the northeast; the positive electricity decreases, and the flashes of lightning are more rare.

"8 *o'clock* 4 *minutes, evening.*—The electricity is at zero; but a rain which follows causes it anew to pass to the negative state; nothing more is perceived of the storm.

"*May* 14, 1813.—During the day the temperature rose to +16° 3 R.; the barometer is several lines below its mean; the wind blows lightly from the SE., and the electricity has a feeble positive tension.

"4 *o'clock* 40 *minutes, evening*—A storm rising on the horizon in the SW.; the positive electricity increases with every flash of lightning, but more rapidly than in the first storm; great drops of water fall.

"4 *o'clock* 47 *minutes, evening.*—The storm is nearer; its distance appears about 4,000 feet. A very vivid flash of lightning, followed by a peal of thunder, suddenly changes the positive to negative electricity, of a nearly equal intensity; at the same time there occurrs a heavy shower. From this point, and while the storm passed to the NW., the negative electricity presented a course opposite to that taken by the positive electricity. The rain continued.

"3 *o'clock* 4 *minutes, evening.*—The electricity became positive anew.

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† Journal de Physique, tome LIX, page 296. 1809.
‡ Voyages dans les Alpes, tome II, § 801, page 220.
§ Journal de Schweigger, tome II, page 377.

"*5 o'clock 12 minutes, evening.*—The electricity becomes negative.

"*5 o'clock 18 minutes, evening.*—The electricity decreases considerably with the rain; but continued negative, and this for a long time, after the rain had completely ceased."

The sudden passage from the strongest positive to the strongest negative electricity is certainly the most remarkable fact in the electrical variations which were exhibited while the last storm continued. Schübler observed that this phenomenon is not rare in stormy weather, and it ordinarily occurs after vivid flashes of lighting or during the sudden showers which often accompany them. This remark of the German philosopher is confirmed by the observations of M. Peltier,* made by means of the rheometer. "On the 16th of June, 1836," he writes to the Academy of Sciences of Paris, "I was awakened at two o'clock fifteen minutes in the morning; a storm was raging on all sides; I ran to my instruments; they denoted 80° of a negative descending current; the vivid flashes of lightning produced only ten to fifteen degrees of decrease of deviation. At 2 o'clock 30 minutes the negative current denoted 70°, when a very powerful flash of lightning occurred; the needle whirled about and stopped at 80° on the other side, where it remained thirty seconds; then it returned to 70°. The storm passed off about 2 o'clock 45 minutes; the needle returned to its zero; then passed to the positive side, where it remained." The sudden changes which occurred in the intensity of the electricity at the instant of the appearance of the flashes of lightning were also observed by this philosopher. He speaks thus on this subject in the same note: "The storm of August 4, 1836, was entirely different from any other; at 2 o'clock in the morning the electricity was at first positive and then negative; the needle advanced gradually towards its *maximum*; then a flash of lightning occurred, and the needle fell back half way; then recommenced its ascending course until the next flash of lighting, which made it retrograde. The progressive course so entirely coincided with the electric changes that I could foretell them by the fall of rain detaching itself from the cloud."

We have already said that Volta and De Saussure observed the frequent succession of the two electricities exhibited by the electrometers when they were exposed to the action of thunder clouds. This frequency of the phenomenon did not escape M. Peltier's observation, who cites, among others, the storm of the 6th of August, 1836, as having exhibited to him at least twenty-five changes. Volta† sought for the cause of these changes in the electrical induction which thunder clouds must naturally exercise on each other. If it be supposed that while a cloud positively electrified produces in the electrometer a positive divergence, another cloud possessing a stronger electricity, but of a contrary nature, happens to come above the former, the electricity of the stronger will, according to Volta, neutralize, at a distance, that of the weaker, and will drive, into its lower part, the electricity opposite to that which existed there at first; or rather the more powerful electricity, after having caused the neutralizing

* Comptes Rendus, tome III, page 147.

† Journal de Physique, tome LXIX, page 343.

of the opposite electricity, will, by virtue of its excess, act directly on the instrument placed at the surface of the earth, producing there a negative divergence. If, afterwards, these two clouds happen to separate from each other, the electrometer must exhibit the positive divergence which it at first had. We may conceive, says Volta, that these clouds, driven by the wind and the different currents of air which appear everywhere to exist in stormy weather, undergo a sort of fluctuating movement sufficient to cause the various electric states which are observed in the electrometer. For the purpose of reproducing, by experiment, an imitation of this phenomenon, Volta placed, horizontally, one below the other, two disks of metal, insulated and movable, charged with opposite électricities. As the distance that separated them was very great, the lower disk, which was negative, produced, in an electrometer placed below it, a negative divergence; but in proportion as the same disk was raised or the other was lowered the negative signs gradually decreased till they sunk to zero, after which the opposite electricity was manifested.

It is very probable that a great number of changes which are observed in electricity during storms are only effects similar to those under discussion. If we unite to them the numerous discharges which, in disturbing the electrical equilibrium at every moment, modify the action, of induction, to which the instruments are subjected, we shall, without difficulty, comprehend that the numerous oscillations ought to be exhibited in the intensity as well as in the nature of their electricity. M. Peltier* thought that these oscillations might also result from the partial electrical changes which take place from the interior towards the exterior of a thunder cloud. In fact, we have seen that, in the way shown by this philosopher, the partial conductability of the clouds gives to them distinct atmospheres—the one exterior and a great number of others interior. When the external atmosphere has escaped by an instantaneous discharge, all the internal masses, which have their own atmospheres, restore gradually to the surface the electricity which it had lost. These partial changes which follow the external discharge of a cloud must be manifest to the instruments placed at the surface of the earth, if the latter have an adequate sensibility; for example, in an electrometer we see the leaves spring out, open, close suddenly, or strike against the armatures without any explosion being heard.

It is after a certain number of these partial discharges that we see the flash of lightning which indicates the discharge from the surface, after which the internal exchanges recommence, and with them the oscillations of the electrometer.

We design to state in the second part of this memoir all the results to which the observations hitherto made on atmospheric electricity lead, in order to present in the same outline the state of our knowledge of this branch of meteorology. We may remark that among these results some of them are derived from observations too limited in number to definitively take rank in science, and that as to others, they were obtained by means of too imperfect instruments, or those of

* Ann. de Chim. et de Physique, 3d series, tome IV, page 423.

which the indications were complicated by elements foreign to those sought; in the mean time we await new observations which may serve to correct them. It is only by means of many series of regular observations, made with proper instruments, that we can hope to illustrate, and resolve the various questions which are raised by the results under discussion.

Confining ourselves to the province of the historian, we proceed to give in the last part of our task an epitome of the information hitherto gained relative to the phenomena of lightning.

PART III.

SUMMARY OF OUR KNOWLEDGE OF LIGHTNING.

CHAPTER I.

OF THE FLASHES OF LIGHTNING.

When the two electricities accumulated in the contiguous portions of two clouds, or of a cloud and a body placed within its sphere of activity at the surface of the earth, have acquired a tension capable of overcoming the resistance the air opposes to their union, an electrical explosion takes place, and we see the lightning dart through the air under different forms, such as, according to M. Arago,* diffused flashes, linear and zigzag streams, and globular masses; the latter having a progressive motion.

Some attempts have been made by Helvig† to determine the velocity of the linear flashes of lightning. His observations by means of the camera lucida have led him to attribute to them a velocity of 40,000 or 50,000 feet in a second; but, as Messrs. Pfaff and Kaemtz‡ observe, so many illusions may have existed in the mode of observation pursued by this philosopher that we can only consider this data as a rough approximation. But we know, according to the beautiful experiments of Mr. Wheatstone,§ that the velocity with which the electric fluid passes through a conducting wire is about 115,000 leagues per second, and we may conceive that the velocity of linear discharges of lightning must be the same. [This does not follow.]

The length of these flashes does not appear to be well known; we have only a single direct determination of this element. In a storm which happened on the 2d of May, 1839, M. Weigsenborn,‖ of Weimar, counted 19 seconds as the time comprised between the appearance of

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* Annuaire du Bureau des Longitudes pour l'an 1838, pp. 249, 255, 257.

† Annales de Gilbert, tom. LI, p. 136.

‡ Dictionnaire de Gehler, tom. I, p. 1001, et Lehrbuch der Meteorologie, tom. II, p. 430.

§ Philosophical Transactions for 1834, 2d part, p. 589.

‖ Comptes Rendus, tom. IX, p. 218. 1839.

a horizontal flash of lightning and the commencement of the report, and he found that the angle embraced by the two extremities of this flash was 75°. By means of these data he calculated the length of the flash observed to be more than 8,932 metres—that is to say, more than 2 leagues. M. Arago,* in his notice of thunder, points out a very ingenious method of obtaining if not the true lengths of the flashes, at least the limit within which these lengths must be contained; but this method rests on the hypothesis that the duration of the peal of thunder is the time which its sound requires to pass through a space equal to the difference in length of the two lines, drawn from the ear of the observer to the two extremities of the flash. In applying it to some observations, M. Arago found for certain flashes the lengths of at least 3.3, of 3.4, and 3.8 leagues. So great a length naturally leads us to admit that the electricity which forms the flash is incomparably greater than that which can be accumulated in the most powerful batteries. But M. Gay Lussac† observes that we cannot really judge of the relative intensity of the electricity accumulated on our conductors and in a thunder cloud by the length of the sparks, since the former are very good conductors of electricity, and are surrounded by air, which in its usual state has little conducting power, while the clouds are tolerably good conductors, and the surrounding air, rarified and saturated with moisture, possesses in a considerable degree the power of conducting electricity. The portion of vapor with which the air enveloping the cloud is probably more or less charged appeared to M. Pouillet‡ capable of serving as a medium to produce a discharge, in the same manner that metallic powders, spread on woolen or silk cloth, cause the spark of our machines to be projected to a greater distance. In order to explain the length of the discharge of lightning he supposes that in the course which it is to take there are patches of vapor, and possibly even those of air, already electrified by the contrary induction of the electricities which have a tendency to rush against each other, and that at a given moment the equilibrium is finally broken without there having been any transfer of the fluid of one cloud to another, but simply the successive transfer of the electricity of one patch to another over the whole path of the discharge.

M. Lamé§ explains the length of the flashes of lightning by supposing that it may be the result of the small excess of the conductibility of the clouds over that of the air between them, and consequently the free electricity of feeble tension, diffused at their surface, may be discharged between two clouds at several points at once, and successively between different portions of each one of these clouds.

It is known that the zig-zag form is common to the flash of lightning and to the electric spark. Helvig‖ sought to determine the exact form by means of a camera lucida, and, according to this observer, it

* Annuaire pour 1838, p. 459.
† Annales de Chimie et de Physique, tom. XXIX, p. 105. 1825.
‡ Elements de Physique et de Météorologie, tom. II, p. 808.
§ Cours de Physique de Ecole Polytechnique, tom. II, 2d partie, p. 82.
‖ Annales de Gilbert, tom. LI, p. 139.

was always under an angle of 40° that the deviation of the flash of lightning was produced; but Brandes* remarks that this determination cannot be regarded as exact, because, in the instrument by which it was obtained the same angle would appear more or less acute, according to the position of the observer's eye. But it would not be without interest to science to have more certain data as to the form of linear discharges of lightning, and the more so as it is thought that some connexion has been discovered between this form and the peals of thunder. Possibly the property which certain substances possess of becoming instantaneously phosphorescent under the influence of the light developed by an electrical discharge, and this at the distance of several yards, as M. Becquerel has shown,† might furnish means of obtaining phosphorescent impressions of the streaks of lightning, and thus determine all the irregularities which the discharge exhibits in its course through the air.

It may be asked, What is the cause which produces the zig-zag forms of lightning? Without stopping to consider the hypothesis of Logan,‡ who regarded them as the result of irregular refractions which the atmospheric vapors and the clouds cause the rays of light to undergo, we shall remark that two different explanations have been given of this phenomenon. According to the first, which is by Parrot,§ it is produced by alternate portions of the air, more or less humid, and consequently of more or less conducting power, which the electrical substance meets in its passage, and which oppose to it unequal resistances in different directions. It is true that the atmosphere contains a great variety of exhalations, and particularly of watery vapor irregularly diffused; besides this explanation agrees with the phenomenon which lightning presents at the surface of the earth, where we see it leave bodies which are poor conductors of electricity for those which offer it a more ready passage; but this explanation is considered insufficient, because it cannot be applied to the ordinary electric spark. In fact, in the narrow space which separates a body from the conductor of the electric machine, we cannot regard the air of a chamber as presenting strata alternately dry and moist, and yet the spark none the less pursues a sinuous course.

The second explanation, which is more generally admitted, is based on the resistance which compressed air opposes to the motion of electricity. Atmospheric air being a slight conductor of electricity, it is natural to suppose that the electricity, in passing through it, drives before it the molecules of which it is composed, from whence results, successively, compressions along the whole line through which the discharge takes place. This effect of an electric discharge is also confirmed by the known experiment of Kinnersley. Compressed air opposing a greater resistance, the electricity will follow the path along which the air is less condensed, and will deviate from its direction in a straight line to traverse that of a broken line.

Linear discharges of lightning ordinarily take place between the clouds;

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* Beiträge zur Witterungskunde, p. 353. Leipzig, 1820.
† Comptes Rendus, tom. VIII, p. 216. 1839.
‡ Philosophical Transactions, vol. XXXIX, p. 240. 1735.
§ Dictionnaire de Gehler, tom. I, p. 999.

but it is not rare to see them launch out from one group of clouds to another; sometimes, even, the electric fluid, after several zig-zag movements, returns toward the region from whence it came. This last phenomenon is frequently observed in volcanic clouds.* Exact observations place it beyond doubt that streaks of lightning sometimes become forked, and are divided into three branches, which often separate to points very remote from each other.†

Mr. Faraday‡ has given a new and ingenious explanation of the phenomena. As he regards them, the different forms which the flashes of lightning take do not belong to the discharges, but to the edges of the clouds behind which they are produced. Let any one imagine a dark cloud, presenting an irregular and well defined border, placed between the eye of the observer and the place of electrical discharge; at the moment when this is effected the cloud will present an illuminated edge, similar to the shining edge which it would exhibit were it placed between the sun and the observer. Such may be, in many cases, the cause of the apparent form of the flashes; what the observer really sees being only the irregular outline of a cloud. Mr. Faraday states that he has frequently been able to verify this opinion, and according to him, we are thus to explain the branching of the discharges of lightning, their return to the region from whence they came, and also the remarkable phenomenon of the flashes having frequently exactly the same form and succeeding each other rapidly in the same point of the sky, without, however, being produced by the same electrical discharge. We readily believe that illusions of this kind sometimes take place; but we have observed the branching of the lightning exhibited under such circumstances that it becomes difficult, not to say impossible, to apply the explanation of the learned English philosopher. For example, the Abbe Richard§ states that he saw a luminous discharge, single at its departure from the cloud, divide itself in two at some distance from the earth, and each half strick a separate object. Here is certainly a case of forking in which the bright line delineated in the space belonging clearly to the discharge of lightning.

The streaks of lightning are not always of the same color. Those which present themselves under the form of a narrow winding discharge are, in general, white; they have sometimes been observed, but rarely, of a purplish violet or bluish tinge. The light of the diffused flashes of lightning neither presents this whiteness nor an equal brilliancy; its tint is often of a very intense red, sometimes mixed with blue or violet. Sometimes it appears only to illumine the edges of the clouds; at others it includes their whole superficial ex-extent. The differences which are observed in the intensity and color of the light of the flashes may depend upon several causes, among which we must reckon more or less the density and moisture of the stratum of the air in which the clouds are found, as well as its greater or less degree of conductibility. In fact, experiment proves that

* Philosophical Transactions for 1795, 1st part, p. 73.

† Annuaire for 1838, p. 252; Dictionnaire de Gehler, tom. I, p. 1000; and Lehrbuch der Meteorologie, tom. II, p. 428.

‡ Philosophical Magazine, vol. XIX, p. 104. 1841.

§ Annuaire for 1838, p. 252.

the density of the media traversed by the spark of our machines singularly influences the brightness and the color of the light produced; that when this density is very small the light becomes diffuse and reddish; that in the case where it is considerable the light is contracted and brilliant. The electrical sparks of our machines have also different appearances, and especially vary their color according to the hygrometric state of the air. They are also generally the more brilliant the better the substances between which they take place conduct electricity. Finally, in the electric explosion occurring between the strata of a cloud lying above another, it may happen, as M. Kaemtz* observes, that on account of the thickness of the lower cloud the light of the flashes, however intense it may be supposed, produces on the eye of the observer only a feeble and diffused light.

The experiments of Mr. Wheatstone show that the duration of the linear streaks of lightning and of diffused flashes does not exceed the thousandth part of a second. It is not the same with the globular discharges, which are sometimes visible for several seconds, and pass from the clouds to the earth with sufficient slowness for the eye plainly to follow their course and ascertain their velocity. Their existence appears to be now well established. Schübler† and M. Kaemtz‡ mention flashes of lightning which had the appearance of a current of fire as large as the arm, terminated by a much larger and more brilliant ball; and Muncke§ saw a discharge which descended vertically, and which must have been about 200 feet long, transformed, under his eyes, into a great number of small balls. These globular discharges, which sometimes leave along their passage inflamed portions, appear frequently in the midst of volcanic storms;‖ the same is the case with linear streaks of lightning; they often become subdivided, and after their explosion they commonly leave a strongly sulphurous smoke. We are as yet ignorant of the cause of the formation of these meteors; they seem to be the agglomerations of ponderable substances strongly charged with electricity. M. Arago¶ thought that it might not be impossible that the lightning in passing through the air sometimes produces instantaneously a sort of half union of substances which may exist in this medium, and thus produce these globular discharges. There are many facts which favors this opinion. First, it is established that lightning, when on its passage through the air, produces chemical combinations, as is proved by the presence of nitric acid in the rain water gathered during storms.** Then the observations of M. Fusinieri,†† confirmed by those of M. Boussingault, on the presence of metallic iron, of iron in different degrees of oxydation, and of sulphur in the powdery deposits which surround the orifices in the bodies through which lightning has forced a passage; the fact that hailstones have for a nucleus small fragments of sulphuret of iron,‡‡ the

* Lehrbuch der Meteorologie, tome II, p. 429.
† Journal de Schweigger, tome XLI, p. 36; 1824.
‡ Lehrbuch der Meteorologie, tome II, p. 427.
§ Dictionnaire de Gehler, tome I, p. 1000.
‖ Philosophical Transactions for 1795, part I, p. 82.
¶ Annuaire pour 1838, p. 426.
** Annales de Chimie et de Physique, tome XXXV, p. 329. 1827.
†† Bibliothèque Universelle, tome XLVIII, p. 371, and tome XLIX, p. 1. 1831 and 1832.
‡‡ Bibliothèque Universelle, Sciences et Arts, tome XVIII, p. 78. 1821.

presence of iron in the rain water which falls from thunder clouds, the odor and vapor of sulphur that the lightning almost always gives out where it breaks forth, appear to establish the conclusion that the atmosphere contains, at least as high as the region of the thunder clouds, iron, sulphur, and other substances. [It is more probable that these substances are carried immediately up from the earth by the force of the discharge.—J. H.] The existence of the deposits, of which we have spoken above, proves that lightning conveys these bodies. Besides it is known that the ordinary electric spark may also convey ponderable substances in a state of great tenuity. It may happen then that the lightning, in passing through the air, may induce a commencement of the union of the different substances which it contains, and that the electricity concentrated there by their conductibility may appear under a form more or less globular. New experiments and new observations, however, can only assign the proper value which this opinion should have in science.

CHAPTER II.

OF THUNDER.

As is the case with every electric explosion, the flash of lightning is accompanied by a noise more or less intense of longer or shorter duration, to which is given the name of thunder. This noise varies with the distance of the observer from the place where the electrical discharge takes place; if it is very near, the flash is almost immediately followed by successive and rapid detonations, but at a little distance these detonations are replaced by a sort of reverberation, which lasts for several seconds, and which is frequently intermingled with violent explosions. Physicists generally are agreed in considering the thunder as the result of the sudden re-entrance of the air into an empty space, thus likening the phenomenon to what happens in the experiment known as the burst bladder, but they differ in opinion as to the manner in which this void is produced. According to some, the flash of lightning is always attended with the sudden formation of rain, and the vapor contained in a large space being suddenly condensed, it must form in the atmosphere, almost instantaneously, a void into which the strata of surrounding air rush by virtue of their elastic force. This rapid motion will produce a loud noise, and as the portions of the atmosphere which have filled the void formed by the condensation of vapor leave in their turn an unoccupied space, new strata of air will rush into this latter, producing a new report, and so on.

It is conceived, also, that the intensity of the explosions must become weakened, since, on the one hand, the cause which produces them loses its intensity, and, on the other, because they take place at distances more or less remote from the observer. To this we may reduce in substance the opinions advanced by De Luc,* Girtanner,† Mayer, and Monge.‡

* Idées sur la Météorologie, tom. II, page 150. Paris, 1787.

† Dictionnaire de Gehler, tom. I, pages 568 and 569.

‡ Encyclopédie Moderne, tom. XXII, page 319. Brussels, 1832.

This explanation is in accordance with the violent showers which ordinarily attend the loud peals of thunder, but numerous objections have been made to it which are difficult to answer in a satisfactory manner. We do not see, for example, why the rapid condensation of vapor into rain should not always be attended by thunder. On the other hand, it has been established that there is sometimes formed, in a perfectly clear sky, a single cloud, the appearance of which is immediately followed by the rapid formation of several other clouds, which spread in a short time over the whole extent of the sky without thunder being heard.

Other philosophers have sought for the cause of thunder in the vacuum generated by the lightning in its passage through the air. Kinnersley's thermometer and many electrical effects prove that the electricity, in traversing the air, drives aside the portions which it meets, producing a momentary void, into which immediately after the surrounding air rushes, with a violence which depends on the intensity of the electricity. Hence the prolonged noise of thunder is the report from all points of the discharge. This explanation was combatted by M. Pouillet,* who remarked that, if this were the cause of thunder, the passage of a cannon ball in the air ought to produce a similar noise, while there is heard from it only a sort of hissing. This philosopher contends that when the spark passes between two bodies the electric fluid experiences no movement of transfer like that of the projectiles of ponderable matter, but that there are decomposition and recompositions of electricity along all the path of the discharge, and consequently there is a vibration more or less violent in the ponderable matter—a vibration which M. Pouillet compares to a kind of tearing apart, or quick separation, as, for example, in the experiment of the perforated card. According to him, the noise is the result of this vibration which afterwards is propagated in all the surrounding mass.

On the subject of this explanation M. Becquerel† observes that there is no proof of the agitation of the particles of the air being sufficient to produce the noise of thunder; and as for the objection drawn from the motion of the ball, as the circumstances are not the same, the velocity of the ball being appreciable, while that of electricity is not so, he thinks that the effects ought not to be alike in the two cases. The velocity of electricity being nearly infinite compared to that of the ball, the vibration of the air must be vastly more intense, and there is nothing to prevent the contractions and expansions of the air from producing detonations with reverberation.

The explanation which attributes the sound of the thunder to the sudden re-entrance of the air into the void produced by the lightning is regarded by M. Tessan‡ as insufficient, and we owe to this observer some new ideas on the formation of this sound. According to him a gaseous conducting body, such as a cloud, changes its form and volume, and which its surface is externally subjected from the surrounding dry air consequently its density, when it is electrified, because the pressure to

* Eléments de Physique et de Météorologie, tom. II, page 809.
† Traité de l'Electricité et du Magnétisme, tom. IV, page 129.
‡ Comptes Rendus, tom. XII, p. 792. 1841.

decreases in proportion as the electrical charge increases, and because the expansion of the electrical clouds is always such that their own elastic force, added to the expansion of the electric fluid, is found to be in every point equal to the external atmospheric pressure. Now, if in this state an electric discharge bursts from a cloud, the external air being no longer retained by the expansive force of the electric fluid which produces the equilibrium will rush from all parts towards the cloud. There will be a condensation and a driving back of the surrounding particles, and consequently a report. Such would be, according to M. Tessan, the explanation of thunder, and the shower that follows it.

A question, the solution of which possibly may not be without some importance in the explanation of thunder, is the existence of flashes of lightning without noise. Many observations tend to prove its existence; and first, do we not often perceive, even in a clear sky, in the beautiful nights of summer, gleams more or less vivid which are termed heat lightning, and which are not distinguished from the flashes of ordinary lightning except that they are not attended by thunder? It is true some philosophers regard these flashes of heat lightning as the reflection on atmospheric strata more or less elevated, of the flashes of common lightning produced in thunder clouds hidden by the convexity of the earth. Experiments mentioned by M. Arago* prove that the feeble light which results from the kindling of several ounces of powder is reflected very perceptibly by the atmosphere; we may then admit that the reflection, infinitely more bright, of distant flashes of lightning must produce similar effects. Moreover, we may observe that there exist observations which directly demonstrate the possibility of this explanation. We find in De Saussure's† work that on the night of the 10th or 11th of July, 1783, this philosopher, finding himself at the hospital of the Grimsel, with a calm and clear sky, saw near the horizon, in the direction of Geneva, several bands of clouds from which darted forth flashes of lightning that produced no noise. Now, the same night and at the same moment the city of Geneva experienced a most terrific storm. But if heat lightning appears sometimes to derive its origin from atmospheric reflection, observation shows that in many cases we cannot attribute it to distant storms. Among others, Schübler‡ states that in some parts of Würtemberg, over an extent of more than 400 square leagues, there were observed on the night of the 26th of August, 1823, from nine to eleven o'clock, flashes of lightning in a sky perfectly clear, without the slighest storm appearing in that whole extent of country. Besides, the fact that heat lightning is sometimes seen entirely around the horizon, may alone suffice to demonstrate that it is impossible always to explain it thus; for it would be necessary to suppose that storms exist at the same instant and in all directions, from the centre at which the observer is placed in a calm and clear atmosphere, a supposition which is scarcely admissible. We may remark again that if heat lightning ordinarily shows itself on the edge of the horizon, it is also sometimes

* Annuaire pour 1838, p. 429. † Voyages dans les Alpes, tom. III, § 1700, p. 470.
‡ Journal de Schweigger, tom. XXXI, p. 39. 1824.

seen at the zenith. A number of physisists likewise regard this phenomenon as existing by itself independently of storms.*

Besides these flashes of heat lightning, frequently in cloudy weather very bright flashes may be seen to pass through the clouds without being followed by any noise.† Perhaps it might be said that the storm is at too great a distance from the observers to hear the thunder, since, according to the calculations of M. Arago‡ a distance of three, four or five leagues is sufficient wholly to deaden the noise of the detonations of the lightning. But to this it may be answered, that during the same storm and in the same clouds frequent flashes of lightning are observed to gleam forth, a small number of which only are accompanied by thunder. It is true that M. Delezenne§ has given, in a similar case, an explanation, based on the phenomenon of interference of the waves of sound; but if this explanation is applicable to the case in which a flash of lightning without thunder is followed by another accompanied with noise, we cannot see how it can be admitted when numerous flashes of lightning succeed each other in silence. Now if it were well established that there are flashes of lightning without thunder, would not their existence be irreconcilable with the explanation which regards the sudden re-entrance of the air into the void left by the flash of lightning as the physical cause of thunder? Observations on cases of lightning supposed to be without thunder, giving the heights and distances of the clouds, in which they appear, might therefore throw some light on the question of the theory of thunder.

Another fact which, if it were confirmed by new observations, would be no less important in regard to this theory, is that of the hissing noise by which a flash of lightning was attended, in a storm which raged on the road from Avignon to Remoulin on the night of the 18th or 19th of September, 1840. "A flash of lightning," says M. Tessan‖ in reporting this observation, "caused a loud hissing sound, attended by a terrific crash of thunder. The flash, the hissing, and the crash appeared to me simultaneous, as well as to two persons who were with me in the front part of the stage coach; I, however, believe that it was rather in the order just mentioned in which the sensations succeeded each other."

Whatever explanation of thunder we adopt, we must not neglect to take into account two remarkable circumstances, which are its long duration and the successive decrease as well as increase of intensity which are so frequently renewed during the reverberations of the same peal. In discussing the point as to what effect echoes may be considered

* Schübler thinks that the flashes of heat lightning are only irradiations of insulated clouds, surcharged with electricity. M. Mattenci has sought for the cause in the electricity accumulated at the surface of certain portions of the earth which have become insulated, either by the nature of the soil which compose them, or by the effect of the evaporation which has dried them up. Finally, Brandes believed that the phenomenon of heat lightning has some relation to the falling stars.—See Lehrbuch der Meteorologie von Kaemtz, tom. II, p. 484; Bibliothèque Universelle, Sciences et Arts, tom. XLII, p. 9. 1829; and Beiträge zur Witterungskunde, p. 354.

† Annuaire pour 1838, p. 295; Annales de Poggendorf, tom. XLIII, p. 531; 1838, &c.

‡ Annuaire pour 1838, p. 442.

§ Traité de Meteorologie, ou Physique du Globe, par Garnier, tom. I, p. 369.

‖ Comptes Rendus, tome XII, page 792.

to have in producing these phenomena, M. Arago* remarks that there is little hope of arriving at anything decisive on this subject. He cites the echoes which have continued during half a minute from the sound of the discharge of a pistol, and from the observations he has been able to collect, the longest peals of thunder are not more than thirty-six, forty-one, and forty-five seconds. The objection has been made that sailors hear the rolling of thunder in the open sea where then there is no terrestrial object capable of reflecting the sound; but observation proves that clouds possess, like other bodies, the property of producing the reflection of sound.† Nevertheless a remark seems to prove, according to M. Arago, that the rolling of thunder does not always result from simple reflected sound when the flashes of lightning succeed each other in a sky uniformly cloudy. Some are attended by long reverberations while others are followed only by short and sharp peals. It is evident that these remarkable differences cannot be explained by considering the rolling of the thunder as a simple phenomenon of echo.

Recourse has been had to another consideration derived from the inequality of time which the noise, produced by the displacement of the air in the different points along the course of a flash of lightning, takes to reach the ear by which it is perceived. Dr. Robert Hooke‡ appears to be the first who observed this circumstance; according to him the different portions of the long line of the flash being in general at different distances, the sounds generated, whether successively or simultaneously, will require different or unequal times to reach the ear of the observer. Hence the length of the flash of lightning would determine the duration of a peal of thunder, and to an observer placed under the line of a flash of lightning, near its middle, the same peal would produce reverberations only half as long as to one placed at the extremity of the flash. This explanation, based on the time necessary for the propagation of sound, has been generally adopted by philosophers. This also accounts in the most rational manner for the reverberation of thunder. As for the changes of intensity so frequently mentioned, Helvig§ regards the zigzags of the flash of lightning as playing a very important part in this phenomenon. He founds his opinion on an observation in which he saw a flash of lightning which, in descending towards the earth made four bends, and produced as many distinct and well defined explosions, but not all of the same force. According to him a change in the direction of a flash of lightning must occasion a change in the sound of the thunder. And in fact, as M. Arago‖ also observes, when a flash of lightning that is proceeding directly from an observer doubles upon itself for a moment, it is evidently a necessary result that there will be an increase of the noise. Farther, this increase will in its turn be followed by a sudden decrease, if by a second bend the flash is brought again to move a little nearer to the visual line, and so on. The changes

* Annuaire pour 1838, page 451.
† Annales de Chimie et de Physique, tome XX, page 210. 1822.
‡ The Posthumous Works of Robert Hooke, page 424. London, 1705.
§ Annales de Gilbert, tome LI, page 139.
‖ Annuaire pour 1838, page 456.

of intensity in the report may also result, according to M. Kaemtz,* from the fact that the compression of air must naturally be stronger towards the apex of the angles where the inflexions of the flash of lightning take place. There would then be, according to these philosophers, a close connexion between the claps of thunder and the zigzags of the streaks of lightning, which it would be important to confirm by direct observation.

CHAPTER III.

OF THE PRINCIPAL EFFECTS PRODUCED BY LIGHTNING AT THE SURFACE OF THE EARTH.

After having followed the lightning in its course through the air and discussed the phenomena which it presents, it only remains for us succinctly to state the principal effects which mark its passage to the surface of the earth.

Definite observations show us that lightning follows the best conductors of electricity which it meets in its passage; that it turns off from its original course to strike metallic masses behind large piles of masonry or even inside of them, when a conductor is wanting or does not offer a passage for its sufficient escape. Though harmless as long as it passes through a metallic rod of sufficient size, we observe it issuing from the extremity of the metal by breaking, pulverizing, or throwing off the substances which oppose its course.

As in the case of the discharge of an electric battery, the lightning in its passage considerably raises the temperature of the conducting bodies, and frequently melts or volatilizes them. It is not unimportant to know what is the greatest thickness of different metals which lightning has been known to fuse, and to assign to this phenomenon the limits that have been observed. M. Arago,† in his notices on thunder, directed his attention to this question, and from the sum of the observations he was able to collect, deduced the following conclusions: that a flash of lightning could melt completely and through its whole length a chain of iron 130 fetet long, of which the diameter of the different links was not above a fourth of an inch; that it might effect the fusion of a conical bar of copper 9 feet long and one-third of an inch diameter at the base; that it could also melt a leaden pipe of 3 inches in diameter and half an inch thick; and, finally, that lightning has never yet brought to red heat a bar of iron of half an inch in diameter.

When lightning traverses conducting wires and the heat which it sets free is not enough to fuse the metal it shortens them. This singular phenomenon was brought to view by the observation of an English

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* Lehrbuch der Meteorologie, tome II, page 434.
† Annuaire pour 1838, p. 305, &c.

experimenter, Nairne,* in which the lightning, after having passed through a tube for conducting rain water, followed a metallic wire, by the aid of which a person could, without going out of his bed, open and shut a gate; after the passage of the lightning it was discovered that this wire was shortened several inches. It is to be observed that the common electric discharge produces the same effect as that mentioned by Nairne, which has been proved by M. Edmund Becquerel.† The latter attributes this phenomenon to the expansive force of the electric spark.

Another effect of lightning, not less remarkable, is the magnetic polarity which it communicates to iron and steel. The packet ship New York, in May, 1827, exhibited a striking example of this effect. When this ship reached Liverpool, after having been twice struck with lightning, Mr. Scoresby‡ discovered that the nails of the partitions and broken panels, the iron work of the masts, the knives and forks, even the points of the mathematical instruments, had acquired a very decided magnetic power. It has also been observed that when the lightning passed near the needle of the compass it changes its magnetism, sometimes entirely destroys it, or reverses the poles. These effects, which are common to lightning and to ordinary electricity, and of which the consequences may be very serious, are not rare; the annals of science furnish a great number of examples.

Lightning, in condensing the particles of imperfect conductors of electricity, sets free sufficient heat to kindle light substances, such as straw, hay, cotton, &c. In forcing its way through sand to reach a sheet of water at a certain distance below the surface of the ground, it instantly fuses together the particles, and gives them the form of vitrified cylinders, called fulminating tubes. These tubes, which are sometimes 30 feet long, 2 inches in outer diameter and a few lines in the inner diameter, are often divided into fragments by long transverse fissures and terminated at their lower extremity by several branches resembling roots. Their inside walls consist of glass uniformly brilliant and pure, while their covering is formed of a crust or grains of agglutinated sand, the color of which varies with the nature of the strata through which the lightning passed. There can remain no doubt as to the origin of these tubes, especially after the experiments ef Messrs. Savart, Hachette, and Beudant § These experimenters obtained tubes of 25 millimetres long with a millimetre of inside diameter, by causing the discharge of a very strong battery to pass through glass reduced to powder. Effects of fusion similar to the fulminating tubes have been observed on the peaks of high mountains; where the surfaces of the rocks present balls and vitreous strata, which alike attest the passage of lightning.‖

Lightning produces mechanical effects of an astonishing intensity. Thus when it bursts into a room it almost always displaces or overthrows the furniture and utensils; tears pieces of metal from

*Philosophical Transactions, Vol. LXXII, Part I, p. 357. 1782.
†Bibliothèque Universelle, nouvelle series, tom. XX, p. 350. 1839.
‡Mémoires de Savants étrangers, tom. IV, p. 709. 1833.
§Annales de Chimie et de Physique, tom. XXXVII, p. 319. 1828.
‖Voyages dans les Alpes, tom. II, § 1153, p. 608.

the places where they were fixed; raises and transfers to a distance masses of great weight, and even has been known to tear from its foundation and transport a whole wall composed of 7,000 bricks, which would weigh 26 tons. These mechanical effects have been differently accounted for by physicists. M. Pouillet* thinks that they cannot be explained by the ordinary laws of electric attractions; but that they depend on a difference in the decomposition of the natural electricities of bodies, according as this takes place by slow or by sudden action. In the first case the conductibility is sufficient for allowing the displacement of the electric fluids, and they have time to arrange themselves at the surface, where they exercise against the air a pressure which is capable of retaining the body in position. In the second case, all the atoms of the mass undergo simultaneously and suddenly a decomposition of their natural electricities; they are acted upon with so much violence that the arrangement required by the laws of equilibrium has not time to be perfected, and the masses are thus acted upon by forces incomparably greater than those which tend to retain them in their position.

M. Arago† has given to these phenomena of transportation produced by the lightning an entirely different explanation. He admits that the lightning in its passage through bodies which contain water developes steam, the expansive force of which is exerted in every direction; so that, if we conceive of moisture being in the pores or cells of a free-stone which the lightning strikes, the sudden development of the vapor will break it, and its fragments will be projected to a distance in every direction. Under the same circumstances the rapid transformation into vapor of water mixed with the stratum of the ground on which the foundations of a house rests will be sufficient, according to M. Arago, to raise up the building in a single mass and transport it to a distance. This philosopher refers, to the same cause, the singular dividing into splinters which wood undergoes when lightning passes through it. It divides it lengthwise into a multitude of slender laths or very fine splinters, and in green wood separates the bark from the trunk; the wood, leaves, and bark are often completely scorched, in consequence of the dispersion of the water, without presenting any trace of combustion.

It is probable that the expansive force of the vapor produced by the passage of the electricity through wood may be the cause of the phenomena which is presented when lightning strikes it, since water which has only reached the temperature of 260° possesses an elastic force of 45 atmospheres; and since the heat developed by lightning in passing through metallic wires is sufficient to melt them, it must raise the temperature of the small quantities of water which it meets in its passage to a high degree.‡ But if the ingenious explanation of

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* Elémens de Physique Expérimentale et de Météorologie, tom. I, p. 613.

† Annuaire pour 1838, page 463.

‡ In advancing the same opinion, M. Becquerel thought that we might explain these phenomena by supposing that the electric discharge meets less resistance in running through the woody fibres in the direction of length than across them; this, according to him, shows an expansive action, and, consequently, a tendency to cleave in the form of laths. Traité de l'Electricité et du Magnétisme, tom. VI, 1tre partie, page 167.

M. Arago is applied without difficulty to the effects which lightning produces in wood, it does not appear to be the same when we seek to give account of the transfers effected by the lightning. It is difficult to conceive how the sudden vaporization of a small quantity of water placed in the fissures of the body is capable of detaching the fragments of a weight of more than two hundred pounds and to send them forth to a distance of nearly two hundred feet, as observation has often proved. It is also by having recourse, as M. Pouillet has done, to electrical attractions that M. Peltier* explains this last phenomenon. It is known that this philosopher regards a thunder-cloud as having two distinct electrical tensions: the tension of free electricity at the surface, and that of electricity retained at the surface of each of the vesicles of vapor. This latter electricity not being able to participate in the igneous discharge produced by the former, since it never leaves the inside of the cloud, continues to act by its tension on terrestrial bodies, and maintain them, in a free state of contrary electricity. It is this powerful tension of attraction which, after the igneous discharge caused by the nuturalization of free electricity, produces, according to M. Peltier, the raising and transportation of the heavy objects with which the strokes of lightning are very frequently attended.

[The simple explanation of the phenomena is that the air in the path of the discharge is instantaneously endowed with an intense repulsive energy, which causes it to expand with explosive violence, and thus produce the observed mechanical effects. J. H.]

Our object being to state only the principal effects of lightning we shall add but a few words on the disastrous effects which are produced when the discharge strikes men and animals. Observation teaches that it kills them, either by producing lesions in the organs and in the vascular system, or by paralyzing the nervous system; they then quickly undergo putrefaction, as is the case with all bodies suffering a violent death. But it sometimes happens that individuals are struck with lightning without being killed, while other persons are known to be killed by lightning without being directly struck. The former fact is to be explained by the consideration that organic bodies being partial conductors, the electric matter may glide over their surface without entering their interior; while the latter is referred to the effect known by the name of the return stroke, the result of a violent action which takes place in the ponderable elements of bodies, by the sudden recombination of their natural electricities decomposed by the electric induction of the thunder-cloud. Finally, it is sometimes the case that lightning sets fire to light clothing on an individual without causing any sensation of burning. This phephenomenon is explained by the property which the electric fluid has of setting fire to all fine substances which enter easily into combustion, and of rarely kindling solid substances.

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* Observations et Recherches expérimentales sur les Causes qui concourent à la formation des trombes, page 94; and Comptes Rendus, tom. X, page 202. 1840.

REPORT

OF

RECENT PROGRESS IN PHYSICS.

BY DR. JOH. MULLER,

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[Translated from the German for the Smithsonian Institution.]

In the portion of the report published this year it has been considered proper to insert notes rendered necessary by later investigations or discoveries. These are suitably indicated, and, as a matter of course, the author should not be held responsible for them. In no case has the original been altered with the single exception noted last year, p. 332.

GEORGE C. SCHAEFFER.

FIFTH SECTION.

THE CHEMICAL EFFECTS OF THE CURRENT.

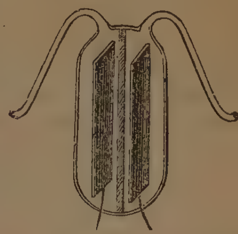
§ 171. *Daniel's researches on electrolysis.*—It may be considered as well established that the chemical decomposition produced by the galvanic current is always proportional to the force of the current, and yet a more accurate examination of the electrolysis of different bodies has disclosed phenomena which cannot satisfactorily be made to accord with this law. If the current passes at the same time through a tangent compass, and through a voltameter, the quantity of detonating gas evolved is *always* proportional to the tangent of the angle of deflection, whether the fluid in the voltameter be diluted sulphuric acid, or a solution of phosphoric acid or of sulphate of soda. Casselman has proved this by a series of accurate experiments in the treatise already mentioned several times.

This seems, at the first glance, to agree completely with the law of constant electrolytic action; but the solution of salt was also decomposed, the acid accumulated at the positive, and the base at the negative pole, and consequently, in addition to the decomposition of water corresponding to the force of current, a part of the salt was also acted upon.

Daniell was the first one who accurately observed and investigated this phenomonon.—(Philos. Transact., 1839, part I, page 97; 1840, part I, page 209; Pog. An., 1842, sup. vol. p. 565 and p. 580.)

In the circuit of a battery of thirty constant zinc-copper elements a decomposing cell of the following construction was inserted. A strong glass cylinder of about 14 inches cubic content and closed at both ends, was cut lengthwise and a porous clay plate inserted between the two halves; the whole was then connected again by means of brass rings with clamp screws. In each of the two cells thus formed a platinum electrode $2\frac{3}{4}$ inches long and 1 inch wide was fastened to a wire passing through the bottom of the vessel. A bent glass tube was ground to the top of each cell for the purpose of conducting off the evolved gas. A preliminary experiment showed that after 24 hours only a very minute quantity of distilled water passed from one cell into the other. Figure 156 is a sketch of this apparatus.

Fig. 156.



The first experiment with this apparatus was the following: Both cells were filled with a solution of sulphate of soda so that the electrodes were just covered; the apparatus was then kept in connexion with the battery until the evolved gases amounted to 29 cubic inches, (corrected for pressure and temperature 28.3 cubic inches.) There were, therefore, 3.6 grains of water decomposed.

The solution at the negative pole was strongly alcaline; it was carefully drawn off with a glass syphon, and saturated with sulphuric acid of known strength, and was thus found to contain 12 grains of free soda. The solution at the positive pole was acid, and by saturating it with a solution of carbonate of soda 15.1 grains of free sulphuric acid were found.

If, now, the atomic weight of oxygen be taken at 100, that of water will be 112.5, that of sulphuric acid 500, and that of soda 390. Hence result the following proportions:

$$112.5 : 390 = 3.6 : 12.5$$
$$\text{and } 112.5 : 500 = 3.6 : 16$$

For one equivalent of the water decomposed, therefore, in one of the cells, nearly one equivalent of sulphuric acid has been separated, and in the other nearly one equivalent of soda.

Several experiments with other salts gave the same result. But this experiment furnishes no datum for determining the relation of the chemical decomposition to the force of current. This relation would have been simply and precisely ascertained if, in addition to the decomposing cell, a tangent compass had been inserted in the circuit. It is to be regretted that this instrument appears to be so little known in England, or at least very little use is made of it. Daniell inserted into the circuit, instead of it, a voltameter filled with dilute sulphuric acid, and found equal quantities of detonating gas evolved in the voltameter and in the cell with sulphate of soda; but it appeared that, besides the decomposition of water, still another effect had taken place in the voltameter, for the acid had accumulated at the positive pole. For this reason Daniell examined more accurately the decomposition of dilute sulphuric acid in a decomposing

cell with a porous diaphragm, and found, after the evolution of a certain quantity of gas representing one equivalent of water, on the side of the positive pole about one-fourth an equivalent of sulphuric acid more, and on that of the negative pole one-fourth an equivalent less than before the experiment. In this case, therefore, besides the decomposition of water, a separation of water from sulphuric acid had taken place analogous to the decomposition of the salt, though only to the amount of one-fourth an equivalent.

This transmission of sulphuric acid to the amount of nearly one-fourth an equivalent of the decomposed water was independent of the degree of concentration of the acid. Daniell modified the experiment in various ways, but always obtained the same result.

A voltameter filled with sulphuric acid, therefore, is not applicable for measuring the force of current passing through the solution of sulphate of soda.

Besides the double cell with the solution of the salt, Daniell then introduced, in addition, fused chloride of lead in the circuit of the battery. It was placed in a bent tube of (green) glass, free from lead, above a spirit lamp; a platinum wire in the fused chloride of lead served as the negative pole, while the positive was formed of plumbago. At the latter chlorine gas was evolved; upon the former the reduced lead was deposited.

Here the following remarkable result was obtained: For one equivalent of chloride of lead decomposed, in the other cell one equivalent of water, and in addition to this one equivalent of salt were decomposed. According to the usual acceptation, therefore, it would appear that in the cell with the solution of salt there was a chemical action twice as great as that produced by the same current in the cell with the chloride of lead; this is in direct contradiction to the law of constant electrolytic action.

In order to avoid this contradiction, Daniell considers the constitution of salts from a quite novel point of view. He considers, for instance, the sulphate of soda not as immediately formed by the combination of acid and base, but assumes the electro-negative constituent of the salt to be one equivalent of sulphur with four equivalents of oxygen, while the positive is only sodium.

According to this view, therefore,

Sulphate of soda is not SO_3. Na.O, but SO_4. Na.
Sulphate of potassa is not SO_3. KO, but SO_4. K.
Nitrate of potassa is not NO_5. KO, but NO_6. K.
Phosphate of soda is not $PO_{\frac{5}{2}}$. Na.O, but $PO_{\frac{7}{2}}$. Na.
Sulphate of copper is not SO_3. Cu.O, but SO_4. Cu.

If the current pass through the solution of such a salt it is not the water but the salt which is decomposed into the constituents just named. In the electrolysis of the sulphate of soda, therefore, SO_4 is produced at the positive pole as a direct effect of the electrolysis, from which (by a secondary action) O is immediately set free, leaving SO_3; while at the other pole the Na. separated takes oxygen from the water, and in this way liberates for each equivalent of Na. an equivalent of

hydrogen; while the Na O, produced by secondary action, remains in the solution.

The electrolysis of sulphate of copper proceeds in the same manner; with this difference only, that the copper, reduced at the negative pole, is not immediately oxydized again, and therefore evolves no hydrogen, but is deposited at the negative pole in the metallic condition.

Daniell also proposes a new nomenclature corresponding to this theoretical view of the constitution of the inorganic salts. He designates, for instance, the combination SO_4 as *oxysulphion*, NO_6 as *oxynitrion*, &c.

According to this view, sulphate of copper is equal to oxysulphion of copper; nitrate of potassa is equal to oxynitrion of potassium, &c.

The experiments with a saturated solution of sal ammoniac perfectly agree with the supposition that sal ammoniac is chloride of ammonium, viz: that it is composed of the simple anion, (the negative constituent,) Cl., (chlorine,) and the compound kathion, (the positive constituent,) NH_4, (ammonium.) The positive pole, made of tin, was dissolved; while at the negative hydrogen and ammonia were liberated, proceeding from the decomposition of NH_4 into NH_3 and H. Sulphate of ammonia is, accordingly, *oxysulphion of ammonium*, $SO_4.NH_4$.

These views also lead to the generalization of the theory of hydrogen acids, which has been repeatedly discussed by chemists, according to which the oxygen acids, containing water, are like the hydrogen acids, binary compounds of hydrogen, with a radical; thus, sulphuric acid would be SO_4. H.

Between hydrate of sulphuric acid SO_4. H and sulphate of soda SO_4.Na, therefore, the same relation would exist as between muriatic acid Cl.H and table salt Cl.Na; the H being only replaced by Na.

But the above mentioned experiments on the electrolysis of dilute sulphuric acid do not fully agree with this view.

If the hydrate of sulphuric acid really is oxysulphion of hydrogen, then it must by electrolysis be decomposed into H and SO_4; but the oxysulphion, liberated at the positive pole, is immediately decomposed into SO_3 and O, the latter escaping as gas, while SO_3 remains in the fluid; therefore for each equivalent of hydrogen liberated at the negative electrode, and for each equivalent of oxygen at the positive, an equivalent of sulphuric acid SO_3 ought to appear at the positive pole; but, according to the above quoted experiments, after electrolysis only $\frac{1}{4}$ equivalent SO_3 more is to be found in the positive cell than had been there before.

The experiment was modified in various ways, but always with the same result. Phosphoric acid behaved in like manner.

By electrolysis the quantity of phosphoric acid in the positive cell was only augmented by $\frac{1}{4}$ equivalent. A similar experiment, made with a solution of caustic potassa, showed that while 1 equivalent of water was decomposed, somewhat less than $\frac{1}{5}$ equivalent of potassa was transferred to the negative pole.

Baryta water gave results similar to those obtained with caustic potassa.

It would have been a great support for Daniell's view if he had succeeded in isolating the hypothetical oxysulphion SO_4. In order to attain this, if possible, he experimented with dilute sulphuric and phosphoric acids, and with a solution of sulphate of soda in an U shaped decomposing cell, provided with a diaphragm below, the leg containing the positive pole being cooled down to o°F, in order, by this low temperature, to prevent the decomposition of SO_4. But these experiments did not give the desired result.

Daniell then experimented with solutions of acid salts. He prepared a solution of *bi-sulphate of potassa.* After electrolysis it was found that for each equivalent of hydrogen evolved at the negative pole one equivalent of oxygen had escaped at the positive pole, but that the cell at the negative pole contained only $\frac{1}{5}$ equivalent of potassa, and that at the positive pole $\frac{1}{2}$ equivalent of sulphuric acid more than before, or, in other words, that for one equivalent of water decomposed $\frac{1}{5}$ equivalent of potassa had been transferred to the negative, and $\frac{1}{2}$ equivalent of sulphuric acid to the positive pole.

This result appears, at the first glance, very complicated, but Daniell succeeded in suggesting a simple explanation. Let us assume that the fluid consists of 3 electrolytes, water, neutral sulphate of potassa, and hydrate of sulphuric acid, or, according to Daniell's designation, OH, SO_4K and SO_4H. If, now, the current is so divided that one-half is conducted through HO, one-fourth through SO_4K, and one-fourth through SO_4H, the direct results of the decomposition will be:

At the positive pole—		At the negative pole.
	From OH	
$\frac{1}{2}$ equiv. O,		$\frac{1}{2}$ equiv. H,
	From SO_4K	
$\frac{1}{4}$ equiv. SO_4,		$\frac{1}{4}$ equiv. K,
	From SO_4H	
$\frac{1}{4}$ equiv. SO_4,		$\frac{1}{4}$ equiv. H.

By the secondary effect the one-fourth equivalent of K takes up $\frac{1}{4}$ equivalent O to form $\frac{1}{4}$ equivalent KO, and thereby $\frac{1}{4}$ equivalent of H is liberated; but at the other side SO_4 separates into SO_3 and O, and thus we have:

At the positive pole—	At the negative pole—
$\frac{1}{2}$ equiv. O,	$\frac{1}{2}$ equiv. H,
$\frac{1}{4}$ equiv. SO_3 + $\frac{1}{4}$ equiv. O,	$\frac{1}{4}$ equiv. KO + $\frac{1}{8}$ equiv. H,
$\frac{1}{4}$ equiv. SO_3 + $\frac{1}{4}$ equiv. O,	$\frac{1}{4}$ equiv. H,
$\frac{1}{2}$ equiv. SO_3 + 1 equiv. O,	$\frac{1}{4}$ equiv. KO + 1 equiv. H,

which, in fact, perfectly agrees with the results of the experiment.

This, also, gave the key to the explanation of the decomposition of diluted sulphuric acid; it is a compound electrolyte, consisting of water and hydrate of sulphuric acid. The current is so divided that

$\frac{3}{4}$ of it is conducted by the water, and $\frac{1}{4}$ by the hydrate of sulphuric acid, and thus we obtain :

At the positive pole—	At the negative pole—
$\frac{3}{4}$ equiv. O,	$\frac{3}{4}$ equiv. H,
$\frac{1}{4}$ equiv. SO_4,	$\frac{1}{4}$ equiv. H,

and by the decomposition of SO_4:

At the positive pole—	At the negative pole—
$\frac{3}{4}$ equiv. O,	$\frac{3}{4}$ equiv. H,
$\frac{1}{4}$ equiv. SO_3 + $\frac{1}{4}$ equiv. O,	$\frac{1}{4}$ equiv. H,
$\frac{1}{4}$ equiv. SO_3 + 1 equiv. O,	1 equiv. H,

exactly as demonstrated by the experiment.

In support of his view of the electrolysis of acid salts Daniell also mentions the fact, that from a neutral solution of sulphate of copper the metal is deposited in a compact mass at the negative pole, and firmly adheres to it; while the copper is deposited in a more pulverulent state when reduced from a strongly acid solution.

In the neutral solution only SO_4Cu. is decomposed, and therefore only Cu. deposited at the platinode; while in an acid solution HO and SO_4H are also electrolized, and, therefore, besides Cu., H is also liberated at the negative pole.

Daniell also relates some additional observations on the electrolysis of secondary combinations. He examined *carbonate of potassa, of soda, and of ammonia,* and found that the carbonic acid and oxygen, both given off as gas at the positive pole, were equivalent to the alkali and hydrogen at the negative pole. He considers, therefore, the carbonates as oxycarbonions of potassium, sodium, ammonium, &c.

Note.—[Daniell's theory of the constitution of salts, although affording, as far as it goes, a simple explanation of the phenomena of electrolysis, is not adopted by chemists at the present time. The theory now becoming general is one which, while it is perfectly in accordance with the whole range of chemical facts, explains, as well as that of Daniell's, everything relating to electrolysis, but is susceptible of far greater extension. In this view salts are considered not as made up of two pre-existing substances, but as a *whole*, a form or type dependent upon laws of nature which we can yet but partly determine. The general expression for a salt will then be R. M., or, rather, R. Mn., in which M. represents a metal, or hydrogen, (a metal,) which may be replaced by any other metal. R, in this case, represents that element, or those elements, which combine with a metal or metals so replaceable. This view is only an extension of that of Davy, which, by a splendid generalization, includes the so-called haloid salts—the chlorides, iodides, &c.—under a common head with the salts of, what are called, oxygen acids. A departure from this view at one time led to the separation of common salt (chloride of sodium) from the very family to which it gave name, and involved an intricate and circuitous explanation of phenomena which were evidently identical.

But the theory of the constitution of salts to which we refer not

only embraces Davy's views, but goes still farther. It not only includes, under a common expression, the salts and the acids, but also the oxides. In this relation it must be distinctly understood that, while the type exists as a whole, and the replaceable metal is also that which, as an element, may be separated from the type, it is by no means necessary that the remaining elements should be, together, capable of a separate existence. Before carrying out this theory in its application to the phenomena of electrolysis, we should, as a bare act of justice, state that it is mainly due to the labors of Laurent and Gerhardt, chemists, who have gained the noble but uncoveted distinction that they have attained their greatest reputation when they have—died.

It is also not a little remarkable that the views of these chemists should now be quoted as supporting a correct idea of electrolysis, when their chief labor was to overthrow the so-called electro-chemical theory. It is quite possible that some other generalization may cause both theories to coincide, (a clue to which has been furnished by these chemists;) but, meanwhile, it is highly instructive to learn that where the nature and reaction of various *elements* are concerned true *chemical* philosophy is able to assert and maintain its own dominion.

To proceed to details without entering into unnecessary refinements, we shall show the electrolytic action upon the salt type, always presupposing the indifference of either electrode to the substances evolved, the metal (or the hydrogen) being eliminated at one pole and the residue at the other, and no secondary effect being produced. As instances of the simplest case we have the following:

From O. H., H. is removed, and O., the residue, is given off at the other pole.
From Cl. H., H. is removed, and Cl., the residue, is given off at the other pole.
From Cl. Cu., Cu. is removed, and Cl., the residue, is given off at the other pole.

Of these water is the most stable compound, and is, therefore, decomposed with the greatest difficulty.

But, carrying out this view, such compounds as Cl. $Cu._2$, &c., are still considered as belonging to the same type; but the metal is regarded as entering into combination with a new equivalent, which is either a simple multiple or fraction of that which usually occurs. This hypothesis, advanced without reference to electrolysis, is strikingly corroborated by the experiments of Becquerel, noticed further on.

But if, with many chemists, we consider water to be O H_2, the ordinary oxides O M_2, (and this is in accordance with the physical properties of the elements,) we will have O M H as a hydrated oxide, which, in the case of O K H, will be more readily decomposed than water alone.

In the instances above given we have noticed only such cases of the saline type, which, on the abstraction of the metallic element, leave a residue, itself an element and capable of a separate existence. But in the "oxygen acids" the residue is not capable of a separate existence and breaks up into such compounds, or compounds and elements, as can exist. As representatives of this class we have S O_4 H, or generally S O_4 M, from which H or M being taken, the residue cannot remain as such, but O is given off and S O_3 unites with water

and remains in solution. Pure $S\,O_4\,H$ (concentrated sulphuric acid) does not afford the water, and the remaining $S\,O_3$ is decomposed by a secondary action.

We are thus able to represent equally well the increased facility of decomposition of water, either by the addition of an acid or of an alkali, (in the latter case secondary action may, however, take place,) and this, too, from a purely chemical point of view, chosen without reference to electrolytic action.

One further remark is required. In the salt type $N\,H_4$ is capable of taking the place of a metal; this is simply a statement of the fact, but in electrolysis this substitution for the metallic element is withdrawn instead of the metals but not being capable of an independent existence, (under the circumstances, if at all,) it appears in the form of hydrogen and ammonia $N\,H_3 + H$. We do not pretend to follow out the cases in which one or more of the equivalents of the hydrogen of the $N\,H_4$ are replaced by some other elements which experience has shown can be introduced instead of them. The mode of reasoning and the consequences will be similar.

It will not be difficult, by carrying out the same theory of the composition of salts to explain the electrolysis of the phosphates and arseniates, noticed in a subsequent part of this report.

Daniell's views, then, are correct, as far as they go, in showing the manner in which salts are broken up in eleltrolysis, but they are in error in considering that the two parts into which the salt is broken are two distinct *substances* which are capable of independent existence. Hence the failure of Daniell in his attempts to isolate his "Oxysulphion," $S\,O_4$, a compound incapable of independent existence.

The difference between these two theories of the constitution of salts, beyond the important fact that one is far more general than the other, may by some be considered as trivial; but this is not the case, for at least one valuable result is obtained, that chemists are relieved from the opprobrium of describing and descanting upon the important properties of certain compounds which they cannot produce and which the most intelligent among them do not deem capable of production or of independent existence.

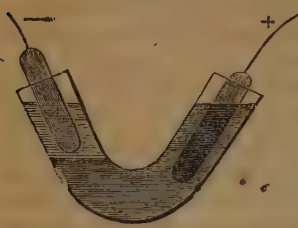
In commencing this note the intention was simply to announce that the hypothesis of Daniell, as to the constitution of salts, was not in accordance with the commonly received opinion of chemists of the present day, and to follow out the latter, with reference to the phenomena of electrolysis, to what were deemed their inevitable results. But, upon examination, it does not appear that any formal announcement of the concordance of the present views of chemists with the laws of electrolysis has been made, though doubtless every intelligent man has followed up this concordance, for it is inevitable. This reflects greater credit upon those who have, in a more advanced state of the science, announced correct purely chemical theories, and upon Davy, who, at a much earlier period, gave the hint of, possibly, a far higher generalization, while still much credit is due to Daniell for leading back the scientific world to sounder views.—G. C. S.]

§ 172. *Deposits upon diaphragms.*—In the memoir just discussed Daniell also describes some very interesting phenomena, the considera-

tion of which, to avoid interruptions, we have deferred, viz: *the deposits upon the diaphragms and the accumulation of the fluid at the negative pole.*

Faraday had already found by placing the positive pole in a concentrated solution of sulphate of magnesia and the negative in water floating upon that solution, (the experiment being most conveniently made in the manner indicated by figure 157,) that by the passage of a very powerful current magnesia was deposited at the surface of contact of the two fluids. In the water oxygen passes toward the + pole and in the solution of sulphate of magnesia magnesium toward the — pole; and when they meet each other at the dividing surface of the two fluids they combine to form magnesia, which is precipitated. Similar observations are noticed by Daniell, in the above mentioned memoir.

Fig. 157.



He filled a glass cylinder, closed at the bottom by means of a piece of bladder, with a dilute solution of caustic potassa, and suspended it so that it just dipped below the surface of a concentrated neutral solution of sulphate of copper in a wider glass vessel. He then placed the negative pole of a battery of twenty cells in the solution of potassa and the positive in that of the sulphate of copper. At the negative pole hydrogen was evolved, at the positive oxygen, while the bladder, from which also some gas arose, was copiously coated with metallic copper interspersed with oxide of copper and blue hydrated oxide. This action is thus explained. The sulphate of copper is decomposed into $S\,O_4$ and Cu.; the former passes to the positive pole, the latter to the bladder, where it is arrested, and gives up its charge to the hydrogen of the other electrolyte, the solution of potassa, which then passes on to the negative pole and is evolved. On the other hand, the oxygen of the solution of potassa on its way towards the positive pole is arrested by the bladder, transfers its charge to the $S\,O_4$ passing in the same direction, and combines with the copper it meets at the bladder. But this action is too rapid for this combination to be complete, a part of the copper is precipitated in the metallic state upon the bladder, while a part of the oxygen escapes as gas.

In fact, the metallic copper diminishes in quantity as the force of current decreases. With feebler currents the bladder was covered with a thick coating of oxide of copper, in which only a few spangles of metallic copper were visible.

From *nitrate of silver* much metallic silver was deposited upon the membrane, mixed with oxide of silver. Gas, too, was disengaged from the diaphragm. The whole of the oxygen was not evolved at the positive pole, but a part of it combined by secondary action with the oxide of silver in the solution to form a peroxide.

Nitrate of lead gave similar results. *Proto-nitrate of mercury* exhibited the most remarkable phenomenon. Not only were globules of mercury formed upon the membrane, but a shower of small globules fell from the diaphragm throughout the experiment.

§ 173. *Accumulation of fluid at the negative pole.*—Porret first ob-

served that fluids are transferred without any decomposition from one electrode to the other.—(Ann. of Philos., Jul., 1816; *Pogg. Ann.* XII., 618.) He divided a glass vessel by a diaphragm of bladder into two cells, filled them with water, and suspended in each a platinum plate connected with the poles of a battery of 80 pairs. In this way nearly the whole of the fluid was transferred to the negative cell. This effect did not take place when the conducting power of the water was improved by the addition of sulphuric acid. Daniell used distilled water in his decomposing cell. On connecting it with a battery of 30 cells, a few bubbles only appeared at the electrodes, but none was disengaged, (in this case again the insertion of a tangent compass would have been very desirable;) but after 40 minutes the fluid at the negative pole was ½ inch higher than at the positive. When a little freshly precipitated alumina was diffused in the water at the positive pole, a portion of this finely divided solid matter evidently passed with the water to the negative pole. When the cell was filled with a mixture of 8 parts of water and one of sulphuric acid, no change of level took place. But nevertheless this phenomenon does not depend upon the conducting power, for it frequently appears with saline solutions, which conduct well, even in a higher degree than with pure water.

When the cell with the porous diaphragm contained sulphate of soda, the fluid in the negative cell rose 1½ inch, while nine cubic inches of oxygen were liberated there; with phosphate of soda the difference in height was 2 inches. Nitrate of potasa produced this transfer in a much less degree.

In order to ascertain whether in this process of transfer the entire fluid was carried over or only the salt, or the water, Daniell examined the specific gravity before and after the experiment without finding any perceptible difference.

Whatever may be the immediate cause of this phenomenon, it appears to have some analogy with the translation of good conducting substances, which in the formation of the luminous Voltaic arc serve as a continuous connexion between the two poles. Daniell believes that this process has no relation to endosmosis.

§ 174. *Electrolysis of polybasic salts.*—Daniell in connexion with Miller extended his researches on electrolysis to still more complicated cases. (Philos. Transact., f. 1844, pt. I; *Pogg. Ann.* LXIV, 18.) Of these we shall now consider more in detail the electrolysis of the different modifications of the phosphates. But to make these interesting phenomena intelligible to those not familiar with the constitution of the phosphates, I shall briefly explain the most important part of the theory, referring for an exceedingly clear exposition of the subject to Otto & Graham's *Lehrbuch der Chemie*, 2d edition, second volume, page 380.

The common phosphoric acid PO_5 forms, with soda, three different salts, viz:

$3N_aO, PO_5$ .... 1.)
$2N_aOHO, PO_5$ .... 2.)
N_aO2HO, Po_5 .... 3.)

the second of which is the common officinal phosphate of soda; it was

formerly called the neutral, while the first was designated as the basic, and the last as the acid salt.

In No. 2, HO, and in No. 3, 2HO are essential constituents of the salt, HO takes the place of one equivalent of base, and thus in all three cases one equivalent of acid is combined with three equivalents of base.

If a solution of acetate of lead is added to that of No. 2, a precipitate of phosphate of lead is produced, which also contains three equivalents of base to one of acid, and therefore consists of 3 PCO, PO_5.

A solution of nitrate of silver precipitates from a solution of No. 2 the tri-basic phosphate of silver 3 A_gO, PO_5, which is distinguished by its yellow color.

This modification of phosphoric acid, which is characterized by always saturating three equivalents of bases, is therefore called tribasic phosphoric acid, and is also designated as *c* phosphoric acid. If three equivalents of bases are replaced by three equivalents of water, this combination gives the *c* hydrate, the ter-hydrate, or the tri-basic hydrate of phosphoric acid.

When the common phosphate of soda 2 N_aOHO, PO_5 is ignited its nature is entirely changed. After being re-dissolved it gives crystals of an entirely different salt, which was formerly denominated pyro-phosphate of soda. By ignition, the equivalent of basic water has been expelled, and thereby a salt obtained which has only two equivalents of soda for one equivalent of PO_5, or is 2 N_aO, PO_5.

On adding acetate of lead bi-basic phosphate of lead is precipitated 2 PCO, PO_5, which, when decomposed by sulphuretted hydrogen, gives the solution of the bi-basic or *b* phosphoric acid.

Graham considers this dilute acid as the solution of the hydrate 2 HO, PO_5, which he denominates deuto-hydrate of phosphoric acid.

When this acid is saturated with bases. two equivalents of the base always combine with one equivalent of acid. The *b* phosphate of soda gives by the addition of nitrate of silver a *white* precipitate of *b* phosphate of silver, while the tri-basic silver salt has, as already mentioned, a yellow color.

By igniting the salt, formerly known by the name of acid phosphate of soda, $N_aO.2HO$, PO_5, the two equivalents of water are expelled, and the mono-basic phosphate or *a* phosphate of soda remains N_aO, PO_5. By adding acetate of lead or nitrate of silver the corresponding lead and silver salts are obtained PCO, PO_5, and A_gO, PO_5. These salts are distinguished by their gelatinous character.

The hydrate of the mono-basic, or *a* phosphoric acid, or the proto-hydrate of phosphoric acid is also distinguished from the other hydrates of the same acid by producing a white precipitate in a solution of albumen.

The *a* and *b* hydrates of phosphoric acid are converted into common phosphoric acid by heating their solutions.

We will now proceed to Daniell's and Miller's experiments on the electrolysis of the phosphates. A strong solution of tri-basic phosphate of soda and water 2 N_a OHO, PO_5 was poured into the negative side of the double cell, and a dilute solution of soda into the other. On passing the current from a constant battery of 20 cups, oxygen was

evolved at the positive, hydrogen at the negative pole. The current was interrupted after 48 cubic inches of hydrogen had been obtained. The fluid in the cell at the positive pole, carefully saturated with nitrid acid, gave with nitrate of silver a copious *yellow* precipitate, *c* phosphoric acid had, therefore, evidently been carried to the positive cell.

A like result was obtained, when instead of the salt 2 N_aOHO, PO_5 a solution of 3 N_aO, PO_5 was put into the negative cell; in this case, too, after the termination of the electrolysis tri-basic phosphoric acid was found in the negative cells. But when, on the other hand, a solution of the bi-basic phosphate of soda 2 N_aO, PO_5 was used on the side of the negative pole, after the termination of the electrolysis it was found that *b* phosphoric acid had been transferred to the solution of soda of the positive cell, for the fluid, when neutralized with nitric acid, gave, on the addition of nitrate of silver, a white precipitate.

Finally, a solution of the mono-basic phosphate of soda N_aO, PO_5 was electrolized under the same circumstances, and the fluid of the positive pole yielded with nitrate of silver, after the termination of the electrolysis, a white gelatinous precipitate, thereby proving that *a* phosphoric acid had been transferred to the positive cell.

Here we have the remarkable phenomenon that the same body PO_5 with equal composition occurs in different modifications, conditions usually ascribed to an allotropic state; PO_5 saturates, according to circumstances, one or two or three equivalents of base. In the electrolysis of phosphates the phosphoric acid always appears at the positive electrode in the same modification in which it was present in the salt of the negative cell. From a tri-basic salt *c* phosphoric acid is transferred to the positive electrode, from a bi-basic salt *c* phosphoric acid, and from a mono-basic salt *a* phosphoric acid.

The view of the constitution of the salts to which Daniell was led by his experiments on electrolysis, and which has been explained in § 171, is in perfect agreement with the electrolytic relations of the phosphates when considered in connexion with the above described peculiarities of these salts.

According to this theory we must consider

3 Na O, P O_3 as Na_3+P O_8, Tritoxyphosphion of Sodium,
2 Na O, P O_5 as Na_2+P O_7, Deutoxyphosphion of Sodium,
Na O, P O_5 as Na+P O_6, Protoxyphosphion of Sodium.

In the electrolysis of Tritoxyphosphion of Sodium, Na_3 is liberated at the negative pole, while P O_8 passes to the positive. By the oxydation of the three equivalents of Na, three equivalents of H are evolved at the negative pole, while at the other pole three equivalents H combine with P O_8 to form H_3+P O_8, that is the *Ter-* or *Trito-hydrate*, so that three equivalents of oxygen must necessarily escape at the positive pole.

In the electrolysis of the Deutoxyphosphion of Sodium, P O_7 passes to the positive pole and evolves two equivalents of oxygen, by combining with H_2 to form H_2+P O_7, that is Deutohydrate, while at the other pole two equivalents of Sodium are formed and two equivalents of hydrogen evolved.

In the electrolysis of the monobasic salt, $P\,O_6$ goes to the positive pole and forms the protohydrate $H + P\,O_6$.

§ 175. *Electrolysis of arsenites and sulphites.*—The English physicists next directed their attention to the electrolysis of salts whose acids had a lower degree of oxygenation than those already examined.

The negative cell was charged with a solution of arsenite of potassa, ($K\,O + As\,O_3$,) the positive with a solution of potassa. At the positive pole oxygen was evolved, but no hydrogen appeared at the negative pole, the electrode being covered with metallic arsenic. According to Daniell's view, K was liberated in the negative cell by electrolysis, and by its oxydation enabled the corresponding H to reduce the arsenious acid ; $As\,O_4$ was transferred to the positive cell, one equivalent of oxygen liberated and the remaining arsenious acid formed with the potassa present arsenite of potassa.

Sulphite of potassa ($K\,O + S\,O_2$) in both the cells gave hydrogen at the negative, but no oxygen at the positive pole ; sulphuric acid was produced in the positive cell, which by acting upon the sulphite evolved some sulphurous acid, K was liberated by the current at one pole and hydrogen evolved by its oxydation ; $S\,O_2 + O$, designated by Daniell as *Suboxysulphion,* was transferred to the other and appeared there as $S\,O_3$.

Hyposulphite of Soda ($Na\,O + S_2\,O_2$ gave similar results. Hydrogen was evolved at the negative pole, and no gas at the positive pole, but a strong smell of sulphurous acid was perceived there, accompanied by a gradual deposit of sulphur. $S_2\,O_2 + O$ passes to the positive pole, is decomposed into $S + SO_3$, and by the action of the sulphuric acid upon the surrounding salt sulphurous acid is evolved.

The experiments on the electrolysis of the yellow and red prussiate of potash we cannot discuss in this place.

§ 176. *Transfer of the bases.*—In the electrolysis of the phosphates the acid was carried into the positive cell filled with a solution of soda. Daniell next endeavored, inversely, to transfer the bases of the positive cell into the negative one filled with acid. With a solution of sulphate of copper and potassa $Cu\,O.\,S\,O_3 + K\,O.\,S\,O_3$ only traces of copper were carried to the negative cell and deposited at the negative pole, but it was found that, compared with the gases evolved, $\frac{1}{4}$ equiv. of potassa had been transferred to the negative cell.

A solution of *sulphate of alumina and potassa* (alum, $Al_2\,O_3$, $3\,S\,O_3 + K\,O.\,S\,O_3$) gave similar results ; potassa was transferred to the negative cell in the same proportion as in the previous experiment, but no alumina.

From a solution of *sulphate of magnesia and potassa* ($Mg\,O.\,S\,O_3 + K\,O.\,S\,O_3$) in like manner only potassa was carried over with a minute quantity of magnesia.

Instead of the double-salts a series of solutions of *sesquisulphate of alumina* ($Al_2\,O_3.\,3\,S\,O_3$,) of *sesquisulphate of iron* ($Fe_2\,O_3\,3.\,S\,O_3$) and *sulphate of copper* ($Cu\,O.\,S\,O_3$) were next introduced into the positive cell and the negative charged with diluted sulphuric acid. Neither alumina nor oxide of iron or copper passed in perceptible quantities into the negative cell. Both the cells were then filled with a solution of sulphate of copper. The metal precipitated at the negative pole,

the solution was deprived of copper; one equivalent of sulphuric acid had passed into the other cell, but the quantity of copper contained in it remained unchanged; no copper, therefore, had been transferred from the positive to the negative cell.

Sulphate of zinc acted in the same manner.

But these results are not to be attributed to the influence of the diaphragm. When a long syphon tube reversed was filled with a solution of sulphate of copper and at the ends two strips of the same metal were immersed as electrodes, the color of the fluid became lighter at the negative and darker at the positive pole.

"By this it appears demonstrated," says Daniell, "that the metals, which are capable of decomposing water at ordinary temperatures, or whose oxides are largely soluble in water, are susceptible of transference in the Voltaic circuit from the zincode (positive) to the platinode (negative pole,) while those which are not marked by this strong affinity for oxygen remain stationary."

On impartially considering the circumstance that some bases, by the electrolysis of the solutions of their salts, do not pass to the negative pole, the idea occurs that, in this case, the salt is not directly electrolized, and does not conduct the current, but that its decomposition is only a secondary phenomenon. When metallic copper is precipitated from a solution of sulphate of copper at the negative pole, while no copper is coming from, but one equivalent of sulphuric acid is passing to the positive pole, it can scarcely be otherwise explained than by supposing that SO_4H is directly electrolized; H goes to the negative pole and reduces one equivalent of copper there, SO_4 to the positive and evolves one equivalent O, leaving one equivalent SO_3 behind. This, it is true, is not in agreement with Daniell's views as explained in § 171, which, however, apply to all those cases where the bases of the decomposed salt also suffers a transfer, as, for instance, in the electrolysis of $KO + SO_3$.

§177. *Becquerel's researches on the laws of electro-chemical decomposition.*—The younger Becquerel has also instituted interesting researches on the laws of electrolysis, (*Ann. de Chim. et de Phys.* Ser. III, T. XI, pp. 162 and 257; an abstract in *Pogg. Ann.* LXV, 461.) Faraday had stated, as a principle, that of the different combinations which may take place between two elements only those are decomposed by the current which consist of an equal number of equivalents of either.

Matteucci had already demonstrated the probability that this principle was not generally applicable, (*Bibl. Univers. Ser. nouv.*, T. XXI, p. 153,) and Becquerel has by numerous experiments removed all remaining doubts upon the subject.

Becquerel first examined several chlorides of metals in the state of fusion as well as in saturated aqueous solutions. In using the fused chlorides the accuracy of the result was disturbed by the circumstance that the chlorine evolved at the positive pole, becoming diffused through the fluid, in part re-dissolved the metal precipitated at the negative pole, thereby making the quantity obtained always too small. For this reason Becquerel mostly employed the metallic chlorides dissolved in suitable fluids, after having satisfied himself that as much metal is precipitated from the solutions as from the fused chlorides,

25

and also that in these solutions the chloride of the metal only is electrolized and not the water, for chlorine was always evolved at the positive pole and not oxygen, as would have been the case if the water, even in part only, had been electrolized.

The solution to be examined was contained in two vessels connected by a syphon, each of which received an electrode. The negative electrode was usually of platinum, while for the positive electrode either this or other metals were used.

If the solution was liable to be decomposed by the air it was covered with a bell-glass, which could either be exhausted or filled with an indifferent gas.

Besides this decomposition apparatus a voltameter was inserted into the circuit; the battery usually consisted of 30 feebly charged elements.

The following table gives the results of a series of experiments:

	Dissolved in	Water decomposed.	PRECIPITATED METAL.	
			Computed.	Found.
		Milligrammes.	*Milligrammes.*	*Milligrammes.*
Chloride of tin, $SnCl$	Water	3.81	24.9	25.0
silver, $AgCl$	Ammonia	1.29	15.5	16.5
iron, $FeCl$	Water	1.5	4.6	5.0
Chloride of copper, Cu_2Cl	Muriatic acid	1.93	6.78	13.5
antimony, Sb_2Cl_3	do	11.0	78.8	51.5
The same, second experiment	do	1.29	9.2	6.0

The 3d column gives the quantity of water decomposed in the voltameter; the 4th, that of the metal which should have been precipitated at the negative electrode if for every equivalent of water decomposed 1 equivalent of metal were deposited; the 5th column shows the quantity actually precipitated.

In the first three cases 1 equivalent of metal, in fact, was precipitated at the negative pole of the decomposing apparatus for 1 equivalent of water decomposed in the voltameter; but in all these cases the electrolized chlorides consisted of 1 equivalent of metal and one of chlorine.

The chloride of copper contains 2 equivalents of metal to one of chlorine, and in this case for one equivalent of water decomposed in the voltameter 2 equivalents of copper were precipitated in the decomposing apparatus.

From the chloride of antimony only $\frac{2}{3}$ equivalent of antimony were obtained, and, in fact, it is a combination of only $\frac{2}{3}$ equivalent of metal for 1 equivalent of chlorine.

By computing the quantity of chlorine carried to the positive pole of the decomposing apparatus, it appears that for each equivalent of water decomposed there was one equivalent of chlorine evolved.

This law was also confirmed by another series of experiments, in

which the precipitated metal was not determined, but the amount of evolved chlorine ascertained by the loss of weight of the electrode, which was of copper. In this manner experiments were made—

With chloride of copper........................	$Cu. Cl.$
chloride of iron...........................	$Fe_2\, Cl_3$.
chloride of tin	$Sn\, Cl_2$.
chloride of antimony....................	$Sb_2\, Cl_5$.

The chlorine computed as equivalent with the water agreed in all these cases with that observed, though only one of the combinations, viz, Cu Cl, has equal constituents of the constituent parts.

Iodides and Bromides gave similar results.

Becquerel also instituted experiments with oxides. He dissolved sub-oxide $Cu_2\, O$ and oxide of copper Cu O, each separately, in liquid ammonia, and closed the flask air-tight by means of a cork, through which the wires of the electrodes passed. Simultaneously with either of these solutions a solution of nitrate of copper, serving as a voltameter, was inserted into the circuit of a single constant zinc-copper element. These experiments, each of which was continued for several hours, demonstrated that for 1 equivalent of copper, precipitated at the negative pole of the voltameter, charged with nitrate of copper, there were deposited—

2 equivalents of copper from the solution of $Cu_2\, O$.
1 equivalent of copper from the solution of Cu O.

The last binary combination examined by Becquerel was oxygenated water $H\, O_2$. For every equivalent of water decomposed in the inserted voltameter two equivalents of oxygen were liberated from the oxygenated water at the positive pole.

The researches on the electrolysis of solutions of different salts lead to results similar to those which we have seen were obtained by Daniell.

Faraday's proposition, therefore, that binary combinations are only electrolytes when they are composed of equal equivalents of both constituent parts proves to be untenable, since many bodies can directly be decomposed by the current which do not fulfil this condition.

In reference to the quantity of decomposition, the result of Becquerel's researches may be best expressed in the words of Poggendorff: that with an equal force of current for every equivalent of water there is also an equivalent of any combination decomposed, provided that it can be decomposed at all.

§ 178. *Formation of chloride of nitrogen by electrolysis.*—When a saturated solution of sal ammoniac, between platinum electrodes, is exposed to the galvanic current hydrogen is evolved at the negative pole, but no chlorine at the positive, and, if the solution is sufficiently concentrated, no oxygen either, but the positive platinum plate becomes covered with small, yellowish, oily drops of chloride of nitrogen.

When spirit of turpentine is poured upon the solution, the rising drops detonate as soon as they come in contact with the turpentine. It is better to place the positive pole not vertically but in an inclined position in the fluid. This interesting phenomenon was discovered nearly at the same time, without the knowledge of each other, by

Kolbe, then sojourning in England, and by Böttger, in Francfort. Kolbe describes the formation of chloride of nitrogen by the electrolysis of a saturated solution of sal ammoniac in Phil. Mag. XXX, p. 336. Böttgen has, as far as I know, never published anything on this subject, but showed the experiment in the laboratory at Giessen.

The formation of the chloride of nitrogen is evidently a secondary effect. If we consider the sal ammoniac as chloride of ammonium H_4 N Cl, then, by the decomposition, Cl. goes to the positive and H_4 N to the negative pole. From H_4 N one equivalent of hydrogen is evolved which escapes, leaving H_3 N, while the nascent chlorine at the positive pole decomposes the chloride of ammonium, producing chloride of nitrogen and muriatic acid. When to chloride of ammonium H_4 N Cl 6 equivalents of chlorine are added, 6 Cl, 4 H Cl, (4 equivalents of muriatic acid,) and N Cl_3 chloride of nitrogen are produced.

§ 179. *Oxydizing effects of the oxygen evolved at the positive pole of the battery.*—The oxygen evolved by the galvanic current at the positive pole has, in its nascent state, strong oxydizing properties, so that it forms combinations into which the free oxygen, under other circumstances, would not directly enter. Kolbe has instituted interesting and important experiments on this subject.

A saturated aqueous solution of chloride of potassium is decomposed between platinum electrodes, by the current from a battery of four Bunsen's cups, in such manner that at first chlorine is evolved at the positive, hydrogen at the negative pole, and free potassa formed, which gives the fluid an alcaline reaction. In proportion as, by the progressing decomposition, the fluid is deprived of chloride of potassium the electrolysis acts also upon the water, liberating at the positive pole, besides the chlorine, also oxygen, which partly escapes, and partly combines chemically with the chlorine, forming at first hypo-chlorous acid, (Cl. O,) and then chloric acid, (Cl. O_5,) which are found in alcaline solution in combination with the potassa.

The formation of chlorate of potassa must certainly, under these circumstances, be considered as the result of the action of the chlorine upon the free potassa. But the same process of decomposition also takes place if to the solution of the chloride of potassium even more sulphuric acid is added than corresponds to the equivalent of the potassium, so that no free alkali can occur, with the single difference that in this case hyperchlorate of potassa (KO Cl O_7) is formed, which usually crystalizes when the fluid, which becomes hot, has cooled again.

Finally, also, from pure muriatic acid, especially when a few drops of sulphuric acid are added, a mixture of free chloric and hyperchloric acid is obtained; while, at the same time, free chlorine escapes at the + pole and hydrogen at the — pole. Hence it appears that chlorine and oxygen, in the nascent state, combine directly, without the presence of any free alkali, while heretofore the so-called predisposing affinity was considered an essential condition to this combination, (as on passing chlorine through a solution of caustic potassa.)

A solution of cyanide of potassium is easily oxydized under similar conditions, and cyanate of potassa (KO. Cy O) is formed. Kolbe could not obtain a higher oxygen compound of cyanogen, corresponding

to the chloric or hyperchloric acid, by the long continued electrolysis of cyanate of potassa; neither did a solution of fluoride of potassium yield an oxygen compound of fluorine.

Kolbe also succeeded in obtaining products of oxydation from sesquichloro-carbohypo-sulphuric acid, $HO + C_2 Cl_3 S_2 O_5$, by means of the current, (Liebig's Ann., vol. 54, p. 157; Philos. Magaz., XXX, 334,) while this acid, under other circumstances, resists the most powerful oxydizing agents, so that it may be boiled with chromic or nitric acid, &c., without undergoing any change.

When a concentrated solution of sesquichloro-carbohypo-sulphate of potassa is exposed between platinum electrodes to the current from a battery of 4 Bunsen's cups, at first no hydrogen is evolved at the negative pole, while chlorine, carbonic acid, and, afterwards, oxygen, are evolved at the positive pole.

As soon as the decomposition commences, an acid reaction of the solution is perceptible, owing to the formation of free muriatic and sulphuric acids. In a later stage of the process, these acids increasing in quantity, hydrogen appears at the negative pole, until, finally, after all the muriatic acid has been decomposed, and the evolution of chlorine has ceased, small octahedral crystals of per-chlorate of potassa are deposited from the solution, which now contains free sulphuric acid and bi-sulphate of potassa.

These results may be explained in the following manner: The oxygen, liberated at the positive pole in consequence of the decomposition of water, acts upon the acid, and causes its separation into different compounds. The oxydation of the acid is complete when it has taken up 12 equivalents of oxygen; the decomposition may then be represented as follows:

$$\begin{matrix} KO + C_2 Cl_3 S_2 O_5 \\ 12\,O \end{matrix} \left\{ \begin{matrix} KO + ClO_7 \\ 2\,SO_3 \\ 2\,CO_2 \\ 2\,Cl \end{matrix} \right.$$

There are formed, therefore, per-chlorate of potassa, sulphuric and carbonic acid, and free chlorine; but the formation of per-chloric acid does not take place in the first instance, for in the beginning of the process chloric acid is produced. If the fluid is evaporated in the earlier stage of the decomposition before the crystalization of the per-chlorate of potassa commences, the well known rhombic plates of chlorate of potassa are obtained.

While the oxygen evolved at the positive pole produces these oxydizing effects, no gas escapes at the negative, since the hydrogen there liberated also enters into several combinations. One part of this hydrogen replaces one or two equivalents of chlorine, and forms acids $HO + \left(C_2 \left\{ \begin{matrix} H_2 \\ Cl \end{matrix} \right.\right) S_2 O_5$, Chloro-formyl-hypo-sulphuric acid, and $HO + \left(C_2 \left\{ \begin{matrix} H_2 \\ Cl \end{matrix} \right.\right) S_2 O_5$, Chloro-elayl-hypo-sulphuric acid—two acids which are described by Kolbe in vol. 54 of Liebig's Annals. Another part of the hydrogen combines with the liberated chlorine and pro-

duces muriatic acid. But these acids are also oxydized at the positive pole, and thus this process of oxydation is continued until the whole of the chlorine in the solution is either changed into per-chloric acid or evolved in the gaseous form.

These phenomena of decomposition may be explained by supposing the decomposition of water to be the primary, the oxydation of the acid the secondary, effect. Daniell's theory of the electrolysis of solutions of salts is here entirely inapplicable. According to this theory, the salt should be considered as $K + (C_2\ Cl_3)\ S_2\ O_6$; the acid combination at the positive pole ought to be separated into two equivalents of sulphuric acid and the insoluble sesqui-chloride of carbon $C_2\ Cl_3$.

The oxydation of the chlorine absolutely requires the supposition of a primary decomposition of water.

§ 180. *Electrolysis of valerianic and acetic acid.*—Kolbe, by subjecting organic substances to electrolysis, and accurately observing the course of their decompositions, has initiated a method which promises to become of great importance to science. We shall here follow Kolbe's researches as far as is necessary for the comprehension of the electrolytic part of the phenomena, without entering upon the discussions of the constitution of the organic substances examined.

Kolbe's memoir on the electrolysis of organic compounds is to be found in full in the Annalen der Chemie und Pharmacie, vol. LXIX, page 257.

Fig. 158.

As free valerianic acid is a bad conductor of the galvanic current, Kolbe used for the electrolytic decomposition a concentrated aqueous solution of its potassa salt. The decomposition-apparatus was arranged, as shown in fig. 158. The glass-cylinder was about 11 inches high and 2½ inches wide. The exterior metallic cylinder was of copper, the interior of platinum foil. The copper cylinder was connected with the negative, the platinum cylinder with the positive pole of a battery, consisting of four Bunsen's cups.

When this apparatus was filled with a solution of valerianate of potassa $KO + (C_8\ H_9)\ C_2\ O_3$, and the current passed, as indicated, through the fluid, a brisk evolution of gas took place at both the poles, and at the same time light oily drops of a slightly yellow tinge, and an agreeable etheric odor appeared upon the surface of the fluid. The very odoriferous gases escaping contained (after all atmospheric air had been expelled from the apparatus) not a trace of oxygen. The mixture of gases consisted of hydrogen, carbonic acid, and a third gas, burning with a brilliant flame, and which gave to the mixture its peculiar odor.

After the action of the current had continued for several hours, the

stratum of oil collected upon the fluid had reached a height of several lines, and the greatest part of the valerianate of potassa had been changed into carbonate and bi-carbonate of potassa, the latter of which usually partly crystalized at the end of the process. In order to ascertain at which pole each of these products appeared, Kolbe placed the platinum plate in a porous clay cell, which was closed air-tight at the top and provided with a tube for conducting off the gas evolved. This cell, filled with valerianate of potassa, was set in a glass vessel also containing a solution of this salt, and in which the copper cylinder serving as the negative pole was placed. With this arrangement it was found that of the above mentioned products of decomposition, besides free potassa, only hydrogen occurred at the negative pole, while all the others, the essential oil, the carbonic acid, and the odorous gas, accompanied by free acid, (the arrangement of the apparatus prevented the formation of carbonate of potassa,) appeared at the positive pole.

Kolbe then proceeded to an accurate examination of the individual products of decomposition. At first he investigated the oily fluid. It soon appeared that the crude oil was not a single substance. By a process which cannot here be described in detail, he found the crude oil to be a mixture of two different substances. After purification, the volume was reduced to about one-half, and the fluid thus obtained was limpid and colorless, of a very agreeable ether-like odor, and of a flat and afterwards burning taste. It is soluble in alcohol and ether, but not in water, boils at 108°, is very inflammable, and of remarkably low specific gravity, viz: 0.694.

The chemical formula of this body, which Kolbe calls valyl, is $C_8 H_9$, *i. e.*, it consists of 8 equivalents of carbon, and 9 equivalents of hydrogen.

The crude oil is valyl mixed with $C_8 H_9 O + (C_8 H_9) C_2 O_3$, viz: with valerianate of oxide of valyl. The odorous gas which escapes with the carbonic acid, is also a hydro-carbon, viz: $C_8 H_8$, and therefore of the same composition as olefiant gas, to which it is also analogous in its relation to chlorine, but its specific gravity is twice as great.

The whole course of these decompositions is now easily comprehended. By the oxygen evolved in consequence of the electrolysis at the positive pole, the valerianic acid $(C_8 H_9) C_2 O_3$ is oxydized and broken up into valyl $C_8 H_9$ and carbonic acid, or rather the valyl itself undergoes again a partial oxidation, and forms oxide of valyl $C_8 H_9 O$, which combines with valerianic acid and produces with the remaining valyl the crude oil. Besides this, a secondary oxidation of the valyl occurs by reason of the nascent oxygen abstracting from it 1 equiv. of hydrogen to form water, whereby the substance $C_8 H_8$ homologous with olefiant gas is produced, which, with the carbonic acid, escapes at the + pole.

Acetic acid undergoes similar decompositions by the influence of the galvanic current. Acetic acid being too poor a conductor, Kolbe also used its potash salt for his experiments. Acetic acid $(C_2 H_3) C_2 O_3$, like valeric acid is oxidized at the + pole, and thereby separated into methyl $C_2 H_3$ and carbonic acid $C_2 O_4$ or rather $2C O_2$,

which both escape as gases at the + pole, while the equivalent of hydrogen corresponding to the oxidizing oxygen at the positive pole is evolved at the — pole. If we consider the pure acetic acid to be combined with 1 equiv. of water, the process is simply explained by the electrolysis of the equivalent of water, and the oxidation of the acid resulting therefrom in the following manner:

$$HO + (C_2\,H_3)\,C_2\,O_3 = \begin{cases} H \ldots\ldots\ldots\ldots\ldots\ldots & 2 \text{ vol.} \\ C_2\,H_3 \ldots\ldots\ldots\ldots\ldots & 2 \text{ vol.} \\ 2C\,O_2 \ldots\ldots\ldots\ldots\ldots & 4 \text{ vol.} \end{cases}$$

The examination of the gasses evolved shows, however, that, in proportion to the methyl, more hydrogen and carbonic acid are contained in the gaseous mixture. But this discrepancy is also easily explained. The process would be as indicated in the above equation if only one equivalent of water was electrolized; but the electrolysis also extends to another part of the water of the solution, and thereby, on the one hand, the quantity of hydrogen is increased, and on the other, a part of the methyl is oxidized to carbonic acid and water, and in this way a greater proportion of carbonic acid is produced. Besides the methyl always contains a small quantity of oxide of methyl.

§ 181. *Electrotype.*—After de la Rive already in September, 1836, (Philos. Magazine, Dingler, Poly. Jour., 105 vol.) had directed attention to the fact, that in a Daniell's battery the precipitated copper can be scaled off from that of the battery, presenting a microscopically accurate copy of its surface, it occurred to Jacobi and Spencer, almost simultaneously as it seems, to make a practical application of this fact. In this they were decidedly successful, as is generally known.

Jacobi first made, in 1839, a Daniell's battery, in which an engraved copper-plate was employed, but he also made at the same time, experiments in a separate decomposing cell, where another copper-plate was placed as the anode opposite to the engraved plate, and thus he kept the solution of the sulphate of copper always saturated.* He also soon found out that an acidulated solution of sulphate of copper is more effective, and that the copper precipitated is pulverulent when the current is two powerful; he observed that generally not more than fifty to sixty grains of copper per square inch can be reduced during twenty-four hours, when it is required to be compact. In order to determine more exactly the force of current he used a common compass. Jacobi soon after published a memoir on this subject, entitled "*Die Galvanoplastik,*" Petersburg, 1840. Spencer's experiments (Dingler's Journal, 75 vol., 1840, and Mechanics' Magazine, No. 846) were, according to him, commenced as far back as 1837; he did not use a separate decomposing cell, but a Daniell's battery, like Jacobi's, with a diaphragm of plaster of Paris, (instead of which unglazed earthenware may also be used,) and common salt with the zinc. The diaphragm was placed vertically in a trough of corresponding dimensions and thus formed the two cells. That the zinc ought not to be amalgamated, and that its thickness should be in a certain, but not

* The phenomenon mentioned in § 176, that the copper does not pass to the negative pole, has here no disturbing influence since the distance of the plates is always very small, and the anode is usually placed above the kathode.

given, proportion to that required for the layer of copper, as Spencer at first stated, has in no respect been confirmed by subsequent experience. Spencer originally intended to fill the traces drawn in a plate thickly coated with varnish, expecting that the galvanic precipitate would adhere firmly to the copper below, and thus serve for printing after the manner of a wood cut; but he never obtained in this way results of any practical value. The reduced copper would not adhere to the plate until the latter had been acted upon by nitric acid. He had already experimented extensively when he first published his researches on the subject. He copied engraved copper-plates by galvanism, or pressed them into lead and used the impressions as moulds, covering the engraved plate while warm with wax, which was afterwards carefully wiped off, for the purpose of preventing the adhesion of the deposit; he also made moulds of plaster of Paris and clay, which were coated with boiled linseed oil, and when this was dry, with mastic varnish, and afterwards covered with bronze powder or gold leaf; these moulds were connected with the zinc plate by a copper wire coated with varnish or sealing-wax.

The original idea of Spencer, to produce types in relief for printing, was afterwards modified by Von Kobell, in Munich.—(Patent of 1841, Dingler's Journal, vol. 95.) He covered a copper-plate thickly with engraver's varnish, which was made to conduct by means of finely powdered and elutriated graphite; larger places, which were not intended to print, (lights,) were separately covered with wax, by means of a brush, and covered with a conducting substance. The entire plate was then covered with copper under the action of the battery. To facilitate the separation, Von Kobell, in previous experiments, already had slightly silvered engraved plates by immersing them in a solution of chloride of silver and common salt. But the same method has been described by Palmer, under the name of Glyphography, in volume 95 of Dingler.

Afterwards the apparatus, when no separate decomposing cell was used, was, according to Jacobi's direction, arranged in the following manner: The zinc was placed horizontally upon pieces of wood or glass, in a wooden or glass vessel, the bottom of which was formed in the smaller ones of bladder, and in the larger ones of stronger animal membrane, or even of tanned calf skin. This vessel was set in another larger one, and suitably supported at a distance of one to four inches from its bottom; upon a copper-plate in the larger vessel the plate to be covered was laid, after it had been carefully greased, and wiped off, or silvered. The edge of the lower plate, so far as not covered by that serving as a mould, was coated with wax. To it were soldered, according to its size, one or more copper wires covered with wax, dipping into mercury cups, into which were led an equal number of wires connected with the zinc. In this way the apparatus could easily be taken apart for inspection when required. The zinc was immersed in very dilute sulphuric acid, as in Daniell's battery, and the mould in a solution of sulphate of copper, kept saturated by powdered crystals suspended in a bag. Into moulds of plaster of Paris, or clay, wires were fastened, which were covered with wax to prevent

the deposit of copper, to obviate difficulty in the subsequent separation of the plate.

In order to separate the copper-plates they were put into a vice and filed around their edges, and when a cleft was observed a horn spatula or other similar tool was introduced to produce the separation, which was assisted sometimes by a gentle heat. The plate first obtained serves again as a mould, but the separation from this is accomplished without difficulty.

Sometimes an apparatus, similar to the one just described, is used, in which several smaller objects are placed at the same time upon the lower copper-plate. When the process is continued for several days, the apparatus has to be taken apart every day in order to remove projections upon the precipitated copper by the file, to renew the acidulated water at the zinc, and also to remove impurities deposited from the solution of the sulphate of copper and from the zinc itself.

But the electric copying of copper-plates was attended by several difficulties. Gerlach, for instance, (Dingler's Journal, vol. 82, and *Journal für Practische Chemie*, September, 1841,) observed that the galvanic copper-plates are very brittle, and that although this property could be removed by the application of heat, yet in this case the linear expansion amounts to $\frac{1}{22}$, which, when unequal, might even produce distortions. Gerlach, from some of his experiments, seems to think that raising the temperature of the plates only to the heat of melting tin might remedy the brittleness without producing the objectionable expansion, but gives no exact information on this point. It was also found that the copy sometimes firmly adhered to the original, or caught in lines which were undercut, and Elsner, therefore, (Dingler's Journal, vol. 80, and *Journal für Practische Chemie*, 1841, vol. 22,) considered it hazardous to subject very valuable plates to this process. The contractions which take place in the moulds, especially when of plaster of Paris, the risk of bending the precipitated deposit on removing it from the mould, or in filling up the back, &c., do not admit of applying the electrotype for copying scales or other measuring instruments. Besides, according to De la Rive, (Dingler's Journal, vol. 99,) such plates stand but few impressions, and especially the lines of wood cuts copied by means of galvanism are said to be frequently hollow, because in deep traces the solution of the sulphate of copper is not properly renewed as it is decomposed, and therefore becomes exhausted, and the deposition ceases until the line overgrows laterally; it is also said that vermilion cannot be used for printing from these plates, because mercury separates, which is not the case with ordinary engraved plates. Vogel, of Francfort, on this account, (Dingler's Journal, 110 vol.,) made impressions, especially of steel plates, in wax, powdered over with graphit, which proceeding was repeated after the impression was made, and removed the excess with a bellows.

An original idea of Vogel was to cover the etched plate after removing the varnish, (an engraved one had previously to be treated with dilute nitric acid,) entirely with the precipitate, then to grind it off again to the original surface of the plate in order to obtain all the traces filled in the manner of inlaid work, (Dingler's Journal, 106

vol.) How far this idea has been practically successful, for instance, by precipitating silver upon iron, I do not know. Knoblauch proposed, (Dingler's Journal, 105 vol.,) by deposition upon a well made copper plate, to produce plates for engravers; because they would be without any defective places and already formed with a plane and polished surface. Stereotype plates may be immediately deposited upon impressions made on wax covered with lead foil. Such plates, as well as electrotype copies of wood-cuts are always made very thin and afterwards tinned on the back by the aid of chloride of zinc, and then filled up with type metal. From wood-cuts, the mould is made either by an electrotype, the surface of the wood having been made to conduct by graphite, or else by impression in wax, &c. But when wood has to be immersed in a fluid, the parts not to be covered should be doubly protected—first, by a coating of sheet lead, and over this again by another of wax. Von Kobell made a peculiar application of the galvanic production of copper plates, under the name of galvanography.—(Presented to the academy at Munich, May 4, 1840.) He painted, after the manner used with India ink, with a solution of damar resin in spirits of turpentine, with the addition of oxide of iron, upon a polished copper plate, and had it galvanically covered with copper without previously making it conducting. The plate thus obtained is immediately ready for printing; the brightest lights are the places where no varnish has been applied. The overgrowing of the varnished places proceeds in part from points of the copper underneath acting through the varnish, but also in part from the uncovered places. But since these plates do not allow of many impressions, they may be multiplied by the electrotype method. Von Kobell has explained this process in a separate treatise.—(Munich, published by Cotta.)

For electrotype copies of other objects than copper plates, moulds usually must be made first. They are obtained either by impressions made in soft lead plates or from clichés in a fusible alloy, or by casts of plaster and wax, or of plaster alone, or else of wax alone, or of a mixture of equal parts of wax and rosin.

As to the metallic moulds no metal can be used which is acted upon by the solution of sulphate of copper, as iron, tin, zinc; these require a previous electro-plating with silver. Böttger, in the Frankfort *Gewerbefreund* of 1840, (Dingler's Journal, vol. 78,) recommends an alloy of 8 bismuth, 8 lead, 3 tin, (melting at 86°R.,) and advises the use of metallic moulds wherever they are applicable. He pours the fused metal into a paper box, stirs it with an iron wire until it begins to thicken, and then presses the object to be moulded upon it until it cools. Impressions in thin lead which has been cleaned with ley, are also recommended by Böttger; they are taken in a press or vise upon moistened pasteboard. Very fragile objects may be covered with lead foil, (tin foil is not applicable,) rubbing it carefully with a little pad of cotton; before taking it off, a mixture of wax and rosin must be poured over it; but for such objects casts are preferable.

For casting moulds with melted wax combined with plaster or with plaster alone, or with a mixture of wax and rosin, it is only necessary that the object to be copied should be surrounded by a strip of paper

and the fluid mass, free from air bubbles, poured upon it; when the mass is cooled and hardened it can be taken off without difficulty. Moulds of plaster of Paris must afterwards be soaked in melted wax to make them water-proof. Gutta percha is also used for moulds; it is slowly heated in water, and when dried exposed to a moderate pressure in a vise in contact with the object to be moulded. To render these or wooden moulds conducting, Spencer, (Dingler's Journal, vol. 77, p. 343,) after finding gilding with gold leaf or dusting with graphite either too expensive or unsatisfactory, took $\frac{1}{300}$ of phosphorus, dissolved it in one part of strong alcohol in a water bath, immersed the mould for some seconds in a weak solution of nitrate of silver, and exposed it to the vapors evolved from the solution of phosphorus heated in a watch glass on a sand bath. Instead of this last process, Böttger proposed to place the mould, when soaked in nitrate of silver, in a vessel into which non-inflammable phosphuretted hydrogen is conducted. The latter is obtained by gently heating in a retort a few small pieces of phosphorus with alcohol and caustic potassa. At present such moulds are commonly powdered over with finely elutriated graphite or finely divided silver, and the excess removed with a soft brush.

The reproduction of round forms by the electrotype offers considerable difficulties; a separate decomposing cell has generally to be used, and the surface of the element must be nearly equal to or larger than that to be coated. Jacobi proceeded in the following manner: He made a conducting surface on a bust, in *alto relievo*, moulded in wax, covered it very thinly by means of galvanism, removed the wax by melting, cleaned the mould thus obtained with spirits of turpentine, and then precipitated upon the inside a thicker layer of copper, from which he attempted to scale off the exterior thin cover, (Dingler's Journal, vol. 78,) but did not succeed without injuring the copy obtained. A Mr. Soyer, in Paris, (Dingler's Journal, vol. 78,) reproduced, in this way, a bust tolerably free from imperfections, and immediately offered to make, for the sum of 200,000 francs, an electrotype copy of the well known great elephant. Fortunately for him, nobody accepted the offer. The Duke Max Von Leuchtenberg followed a similar method, (Dingler's Journal, vol. 80.) His electrotype operations are conducted on the grandest scale, as may be seen from the fact that the black powder deposited on the copper anodes, from impurities in the copper and sulphuric acid employed, and which had to be removed every twelve hours, amounted in a period of about two years to forty "puds," (about 1,444 pounds.)

In the laboratory of Stiglemeyer they were not more successful in reproducing statues on a large scale. A Mr. Moyle, (Dingler's Journal, vol. 80, Sturgeon's Annals of Electricity,) says that he produced such figures over moulds of wax, which he afterwards melted out, but alleges that he has also obtained with silver results of the greatest perfection. The Society for Encouraging Industry, in Prussia, offered a premium for the electrotype production of a larger statue, which was awarded to Mr. Von Hackewitz, (Dingler's Journal, vol. 108; Transactions of the Society of 1848.) He made, over the model, a mould in pieces, of two parts wax, two turpentine, one rosin, and five

graphite; rendered first the lower pieces and their joints conducting, and suspended zinc in dilute sulphuric acid in bags of animal membrane so that it was nowhere in contact with the mould. He then added the solution of the sulphate of copper and connected the zinc with the conducting mould. When the first thin coating was formed in two successive pieces of the mould, they were placed together, and the zinc in the bag put in conducting connexion with the joint; more copper was then precipitated, and in this way the separate thin pieces were united into one. In this manner all the parts of the statue were connected, with the exception of the arms, which were made separately in a similar way. As no bags with zinc could be introduced into the very narrow parts, separate batteries had to be used in such cases for the first coating. Such a procedure may be adopted for the sake of obtaining a premium, but it certainly proves that so far no really practical results have been obtained. A method similar to that used in this case for uniting the separate pieces has been employed for soldering copper rings by means of galvanism; the rings are protected by varnish, but the surfaces to be joined are left bright, and the copper is deposited until the whole space is filled.

A peculiar application of the electrotype was made by Mallet and Meillet, in covering glass and porcelain vessels with a thin copper coating on the parts to be exposed to fire. Mallet covered the vessels with Canada balsam and graphite, but Meillet used gum and nitrate of silver dried in a flame; intense heat, however, destroys this conducting coating between the vessel and the copper deposited upon it, which latter becomes loose. M. Simson, in 1843, proposed (Dingler's Journal, vols. 89 and 91) to act upon the places to be covered by a deposit of copper with hydrofluoric acid to remove the polished surface, and then to rub them over with graphite by means of a cork. Mohr saw such vessels in the Paris exhibition of 1844; reported on them as quite new in Dingler's Journal, vol. 103, and tried to imitate them. But he used copal varnish and bronze powder, and therefore his coating was only firm where it could embrace the vessel, as in retorts, but not in evaporating dishes. Afterwards experiments were again made on this subject by Elsner.—(Dingler's Journal, vol. 108.) He again made use of varnish and graphite, and also applied the etching process; when the places had been covered with a mixture of flour-spar and sulphuric acid for twenty-four hours, and then, after washing, rubbed over with graphite, the deposit adhered firmly even upon evaporating dishes, exactly as stated by Simson years before, though Elsner does not mention this. It has been attempted by Mallet to connect glass tubes in this manner; their ends were ground even, and for a distance of one-half to one inch rendered conducting by means of varnish and graphite. But the joining of the ends as well as the immersion of the tubes present peculiar difficulties. For the latter purpose the vessel must be perforated, and the openings closed with clay after the introduction of the tubes, before pouring in the solution of sulphate of copper.

Talbot, Steinheil, and also Wheatstone have experimented in re-producing metallic mirrors by the electrotype process. Talbot endeavored to make the copper mirrors white by exposing them to the vapor of

hydrosulphuret of ammonia, but Steinheil gilded them. The original metallic mirrors can be used as moulds without any special preparation. Steinheil took great care to obtain the first deposit perfectly pure; for this purpose he made use of a separate decomposing cell, and immersed a proof-plate first to ascertain whether the action was regular and the precipitate even and rose-colored. Afterwards he placed the mould in an ordinary, simple apparatus, and continued the operation until the mirror was one inch thick. Projections, &c., he removed every day with a file. As yet this process seems to have led to no practical results.—(Dingler's Journal, vol. 99.)

Electrotype copies of daguerreotypes, which had been previously gilded, (Dingler's Journal, vol. 91, Philos. Magazine, September, 1843,) were proposed by Draper; but they appear to have led to no result, or at least not to that desired. Still less practically successful was Napier's process; he deposited copper upon linen cloth in order to make it water-proof. The weight of this coating was intended to to be only 12 ounces per square yard.—(Dingler's Journal, vol. 91.)

In order to procure the solution of sulphate of copper required for such purposes at a less price, Schubert advises (Dingler's Journal, vol. 81; Erdmann & Marchand's Journal für Practische Chemie, 1841, No. 11,) to buy from coppersmiths the copper ashes (scale,) to mix them with sulphuric acid of 15–20° Baume to the consistency of paste, and let them remain thus for twenty-four hours upon plates of stone ware, and then wash them with sulphuric acid of the same strength. This last process is to be repeated until either the copper ashes are exhausted or the acid is saturated. The former is the case when the ashes on being moistened no longer become red, and the latter is seen from the saturated color and the cessation of the acid reaction. Instead of fresh sulphuric acid in the after washings, the fluid may be used which has been partially exhausted in the electrotype process.

§ 182. *Gilding, silvering, &c., by means of galvanism.*—It had already been observed for some time that in certain cases metals precipitated in a compact state and adhered firmly to pole wires immersed in metallic solutions, and it had also been suggested that in this way an entire coating of one metal upon another might be obtained; but De la Rive first made a distinct application of this by showing how a solution of gold must be decomposed by means of galvanic currents, in order to coat an object, when forming the negative pole, uniformly with a thin layer of gold.

De la Rive (Dingler's Journal, vol. 76; Comptes Rendus, 1840, p. 578,) used a solution of chloride of gold—40 to 80 grains metallic gold to 1 pound of water—in a bladder, and suspended it in water, acidulated with "a few drops" of sulphuric acid, in which the zinc was placed; the object to be gilded was connected with the zinc by means of a copper wire, and immersed in the solution of gold; after a short time he took it out, washed it, rubbed it well with a clean linen cloth and immersed it again, and he repeated this several times. After a few immersions he considered that the object was sufficiently gilded, and that a longer continuation of the operation was of no use. Among the reasons which led him to this process he mentions the following: "3. The property of the electric current of passing the more readily from a fluid

to a metal, and *vice versa* the more readily this metal is acted upon by the fluid. In the case given the metal immersed in the solution of gold is more easily attacked than the gold itself; as long, therefore, as the immersed part is not entirely gilded, the current will seek the points in the metal to be gilded which are still uncovered, and will deposit gold upon them, whatever may be the length of the path it has to traverse through the liquid, *i. e.*, however irregular the form of the object to be coated." The objects to be gilded had a clean metallic surface given to them, and remained after the gilding either *malt* or polished, as they had been before. The gilding thus produced by De la Rive was therefore in all cases only thin; he gave no quantitative indications either of the force of current or of the weight of the gold precipitated. At first De la Rive gilded directly only silver and brass; iron had to be previously coated with copper. Böttger repeated these experiments with a solution of gold as nearly neutral as possible, and thought that he observed a reddening of the object when the conducting copper wire was immersed in the solution of gold. He says that copper cannot be gilded at all when the solution of gold contains even but traces of copper; then copper only can be precipitated, and De la Rive, according to him, must be mistaken in his statement of the necessity of previously coppering iron objects; he succeeded very well in gilding steel pens, &c., without the use of copper.—(Dingler's Journal, vol. 78; Frankfurter Gewerbefreund für 1840, No. 10.) With chloride of platinum objects can in the same manner be thinly platinized. Böttger considers 5 to 6 immersions of one minute each sufficient for a strong gilding.

Iron can certainly be lightly gilded with chloride of gold without previously being coated with copper, and Arago laid before the academy a watch-spring gilded by Dent (Dingler's Journal, vol. 80, p. 399, Compt. Rend., vol. 12, 1841, p. 779,) and stated that a Mr. Perrot, at Rouen, had previously already done the same thing, but would not present it to the academy before he had gilded an entire watch while it was going! But the gilding and silvering process only became practically useful after the employment of the cyanogen compounds. Elkington had a manufactory of jewelry at Birmingham, where the gilding and silvering were done by immersion, and where also experiments were made in gilding with chloride of gold by means of galvanism. But when John Wright, a surgeon, had made use of the compounds of cyanogen, Elkington at once understood the great importance of the matter, and bought the right of this invention to incorporate it in the specification of his process of gilding, for which he had just applied for a patent. In France, also, he procured a patent, and there had to compete with Von Ruolz, whose patent was of an earlier date by some days. Afterwards they formed a partnership.

Elkington always employed a separate decomposing cell, and used for gilding either three pounds cyanide of potassium, ten pounds of water, and five ounces of oxide of gold, or two pounds cyanide of potassium, ten pounds of water, and two ounces of oxide of gold; thick coatings in this process became *matt*, and had to be scoured with a wire brush. Iron had to be coppered; for this purpose it was placed

in contact with zinc in sulphuric acid diluted to one-half until it was perfectly clean, and then in an acidulated saturated solution of sulphate of copper in a brass vessel, with which the iron was brought in contact. V. Ruolz used either cyanide of gold dissolved in cyanide of potassium, or cyanide of gold in prussiate of potash, (yellow or red,) or else sulphuret of gold in neutral sulphuret of potassium; and though the latter is reported as the best by the commission which examined the subject, (Dingler's Journal, vol. 83, Comptes Rendus, November, 1841,) their experiments were all made with the cyanogen compounds only. In one of these experiments one gramme of dry chloride of gold was dissolved in 100 grammes of water with ten grammes of yellow prussiate of potash, and the battery used consisted of six Daniell's elements, each plate of which was two decimetres square. The precipitate was found to be proportional to the time, and amounted, on a brass plate of fifty square centimetres, to 0.063 grammes of gold per minute when the fluid was heated to 60° C., 0.0296 grammes when heated to 35°, and 0.0126 grammes with a temperature of 15°; while, according to the comparative experiments of Dumas, with fire gilding upon a like surface, 0.1297 grammes were deposited as a maximum, and 0.0214 grammes as a minimum, and by the wet way only 0.0137—0.0211 grammes.

Similar results were obtained by the commission with solutions of one part of cyanide of silver in 100 of water and ten of yellow prussiate of potash. But with cyanide of platinum the coating was one hundred times slower; with the double chloride of platinum and potassium dissolved in caustic potassa, the commission of the Academy states that the results were equal to those obtained with gold. The experiments in coating with copper, tin, cobalt, and nickel, are very superficially reported; of nickel, its easy precipitation upon iron is only mentioned, and in coating iron with zinc its favorable electrical action in protecting the iron is pointed out, while V. Ruolz afterwards alleges (Dingler's Journal, vol. 86, Comptes Rendus, August, 1842, No. 6) that iron covered with zinc is more easily rusted at bare spots than that coated with lead or tin; which experience is also confirmed by Elsner, (Dingler's Journal, vol. 88.)

The circumstances which were concerned in producing these contradictory experiments are not to be ascertained from the respective memoirs. But when the commission adds, "We are convinced that, by this process, iron can be coated with brass; it needs only that copper and zinc should be precipitated upon it, and then the object, surrounded by coal dust, is to be heated to redness, whereby brass will be produced," it appears very much like a conviction obtained at the desk, and may be considered as that additional part of the new invention which every such commission thinks it a matter of duty to contribute.

The new process met with general favor, and it was soon found that equally good results were obtained with a solution four to six times more dilute, and that the use of one element only, or of the simple battery in which the zinc was placed in a solution of table salt, was more convenient. But with large quantities of the solution, and

a long continued operation, the odor of prussic acid proved injurious,* and the prussiate of potash frequently produced a bluish green sediment, (Elsner, Dingler's Journal, vol. 88,) while the cyanide of potassium was too expensive, before Liebig had made known his new method of preparing it. At first, also, the gilding was not made heavy enough, singular notions of saving gold being then prevalent, and in this way the process fell into disrepute with the public, and, in fact, fire gilding can never be made so poor as that done by means of galvanism. At first, too, especial importance was attributed to the fact that the articles could be entirely finished before exposing them to the process of gilding, and only after some experience it was ascertained that heavy gilding was always without polish (*matt;*) that by the use of varnish or wax certain places could be protected against the deposit of gold was immediately observed by Ruolz, and it was also soon known that a reddish hue might be given to the gilding by the addition of cyanide of copper.—(Elsner, Dingler's Journal, vol. 88.)

At the present time the cyanide of potassium usually employed is that prepared after Liebig's method, as any one can make it for himself, although it is still rather expensive, as the product is small for the quantity of material employed. The following is Liebig's direction, (Dingler's Journal, vol. 84, from the Annalen der Chemie und Pharmacie, Marz, 1842:) Eight parts of prussiate of potash are to be thoroughly dried by gentle calcination upon a hot iron plate; then powdered and intimately mixed with three parts of dry carbonate of potassa; put at once into a Hessian crucible previously raised to a dull red heat, and which has to be kept at this temperature; the mixture melts to a brown magma, with a lively evolution of gas; after some minutes, when the fluid mass becomes red hot, the color grows lighter, and after prolonged fusion the contents of the crucible appear limpid and amber yellow. If, from time to time, a hot glass rod is immersed and then withdrawn, the adhering substance, when cooled, at first is brown, after a while it is yellow, and at last, when the operation is finished, the drop on the glass rod is limpid and colorless like water, and congeals to a perfectly white crystalline mass.

During the fusion brownish flakes are seen floating about in the fluid, which unite at last into a sponge-like mass, and assume a light gray color. If the crucible is then taken from the fire and somewhat cooled, in most cases the whole of this gray powder settles at the bottom; by stirring once or twice with the glass rod this deposition is facilitated. The supernatant fused mass can now easily be poured out into a heated porcelain dish, so that, with a little care, not a particle of the sediment passes over.

This mass is then broken to pieces and preserved in well-closed vessels, as it readily deliquesces and decomposes when liquified.

The solution of gold is prepared in the following manner: The gold is rolled thin, cut up, and then heated in a porcelain dish, on a water bath with seven times its weight of muriatic acid, to which

* In this case ventilation is the only applicable remedy; but, in addition, the cyanogen compounds produce all the symptoms of poisoning with prussic acid when brought into contact with sore hands, &c., and the greatest precaution is certainly advisable.

nitric acid is added, from time to time, until all the gold is dissolved, or ten to twelve times its weight of aqua regia may at once be taken; the solution is then evaporated to dryness. The chloride of gold thus obtained is dissolved in water, and the yellow protechloride separated by filtration; carbonate of soda is then added until a feeble alkaline reaction is observed, and at last the solution of cyanide of potassium (one part of salt to ten to twenty of water) is stirred in. When all is well dissolved, and the solution, which at first appeared turbid, is again clear, it is boiled for half an hour. When the color of the gilding becomes impure, carbonate of soda is again to be added, and the boiling repeated, or more cyanide of potassium may be used, especially if the gold at the anode is no longer perfectly dissolved.—(Ryhiner, Dingler's Journal, vol. 110.) A fine red color is obtained when the process is carried on at a moderately elevated temperature. The silver solution consists of one part crystallized nitrate of silver in thirty-two distilled water, to which solution of cyanide of potassium is added until the precipitate which at first appears is again dissolved.—(Elsner, Dingler's Journal, vol. 88.) Freshly precipitated and well washed chloride of silver is also used; as much of this is stirred at intervals into a solution of one-tenth cyanide of potassium in one of water as can be dissolved, and then as much more cyanide of potassium and water is added. This solution may also be used for electrotype silver work. For the copper solution, one part of sulphate of copper in twelve of water are used, and the process conducted as with the silver. But coppering does not succeed well with a single pair; a battery of at least two or three elements should be used.

I omit here a number of suggestions in reference to the use of other compounds, because they never came into practice, and I shall only mention that the addition of a minute quantity of sulphuret of carbon is especially favorable to the precipitation.—(Millward and Lyons, Dingler's Journal, vol. 108, from the Repertory of Patent Inventions, February, 1848.) Five ounces of sulphuret of carbon are mixed with six quarts of the gilding fluid, and of this mixture two ounces are daily added to every ten quarts of the solution of metallic cyanide. This is confirmed by Elkington, at least for silver.—(Dingler's Journal, vol. 114, from the Practical Mechanic's Journal, October, 1849.) Peculiar difficulties occurred in the platinizing process as well as in that of coating with nickel, and so far all the progress made seems not to have rendered the processes practically applicable. According to Fehling (Dingler's Journal, vol. 86) and Böttger (from Annaden der Chemie und Pharmacie, September, 1843, vol. 90,) the best results are obtained by adding a little ammonia to the chloride of platinum and ammonia. Böttger also recommends a similar process for nickel; but the preparatory purification of the commercial metal is very troublesome.

In coating iron with zinc by means of galvanism (Pelatt, Dingler's Journal, vol. 95, from Technologiste, February, 1845,) an acid solution of sulphate of zinc, with a large anode of this metal, must be used in order to obtain a durable deposit.

The different plans for gilding iron and steel without previous coppering are omitted here, and I refer for those of Desbordeaux to Ding-

ler's Journal of 1845 and 1846. So far they have had little or no practical success.

The idea of precipitating alloys, mentioned in the report of the academy, though it there is represented as already confirmed by experiment, was afterwards carried out by Von Ruolz. He actually succeeded in depositing bronze upon iron, specimens of which he presented to the academy, but found that the proportion of the metals in the solutions should be different from that in the alloys required. Von Ruolz dissolved, in 500 parts of water, a sufficient quantity of cyanide of potassium to produce a solution of 4° Beaumé, and added, at a temperature of 40°—48° R., first, 30 parts of cyanide of copper and then 10 of oxide of tin; from this deposits with 10 to 20 per cent. of tin were obtained. Afterwards Jacobi also took up this subject (Dingler's Journal, vol. 93, from Bulletin de St. Petersbourg) and prepared a brass solution by using, in a solution of cyanide of potassium, an anode of copper and a kathode of platinum, until the latter became covered with copper; he then used an anode of zinc until the precipitate assumed the desired color; after this he was able, by using an anode of brass, to coat iron with brass. Although I made many trials I could never succeed in precipitating brass in this manner, the color of the deposit soon changed and the brass anode became black; from some remarks it seems that Jacobi had a similar experience. But I have obtained strong and adherent coatings of brass upon iron by using, instead of a brass anode, one of copper and zinc together, each of which metals could be immersed to a greater or less depth, until the desired color was obtained. This is in accordance with the experience of Von Ruolz.

That gold can be precipitated, alloyed with copper, has already been mentioned; but it is considered better to deposit at first a layer of pure gold before adding the cyanide of copper to the solution of gold.

When the metallic solutions become exhausted by use, either the force of the current has to be increased or some of the concentrated solution must be added. But at present the anodes are usually made of the metal to be precipitated, and by these the solution is kept at the required state of concentration; formerly the anodes were always made of platinum. This expedient has already been mentioned by Petzhold, in his memoir, "Die galvanische Vergoldung, Versilberung und Verkupferung, Dresden und Leipzig, 1842;" and Jacobi, in his treatise on coating with brass, remarks that it is not at all necessary to make metallic solutions in a chemical way; that the solution may be obtained by using, in a solution of cyanide of potassium, an anode of the required metal and kathode of platinum, until the metal deposits upon the latter. Such anodes are made of thinly rolled sheets of the metal soldered to a platinum wire. In silvering, anodes of silver are only applicable with strong currents, or cyanide of potassium in excess; because, according to Napier, (Dingler's Journal, vol. 95, from Philosophical Magazine, November, 1844,) cyanide of silver is formed which is insoluble in water, as well as in neutral cyanide of silver and potassium. According to Napier's researches, the cyanide of potassium is not decomposed while silver is in the solution.

In this same way gold, &c., may also be removed from objects when used as anodes. This may be done with advantage when an object, by improper management of the gilding, assumes a blackish color. But cyanide of potassium is also a solvent for gold without the galvanic current.

As to the strength of the current, experience has taught that it must be very small, so that no bubbles of gas, or scarcely perceptible ones, should appear on the metal to be coated. Deposits slowly formed are more compact and adhere more firmly to the surface beneath them.* The durability of the galvanic coating was at first doubted, and Becquerel even proposed (Dingler's Journal, vol. 89, from Comptes Rendus, July, 1843) to first amalgamate the piece to be gilt with nitrate of mercury, to gild it and then subject it to the common coloring process, which requires a degree of heat sufficient to expel the mercury. The want of durability in galvanic gildings seems, at first, not to have been attributed to its true cause, viz: the thinness of the deposit. Baral (Dingler's Journal, vol. 105, from Comptes Rendus, May, 1847,) dissolved objects which had been subjected to the process of fire gilding, and also such as had been gilded by means of galvanism, in order to examine in both cases the film of gold, and found the galvanic coating to have more continuity, but believes that it is less adherent, because in fire gilding a double amalgam is formed, and after the expulsion of the mercury a part of one metal is left intermixed with the other. But if we take into consideration that the coating produced by fire gilding is more porous and consequently more readily worn away, we shall feel inclined to trust in the durability of the galvanic precipitate. But, besides, experience has shown that galvanic gilding is as durable as that produced by the old process, provided it is of the same thickness. Objects silvered by means of galvanism often turn yellow after a while, but this may be prevented by soaking and washing them carefully in warm water, when taken out of the silvering solution, (Dr. Philipp, Dingler's Journal, vol. 92, from the Berliner Gewerb-Industrie und Handelsblatt, 1844, No. 2.) Objects that have become yellow can be made white again by coating them with a paste of charred cream of tartar and water, and when this is dried by heat, boiling them in an aqueous solution of cream of tartar; they must then be well washed and dried.—(Elsner, Dingler's Journal, vol. 93.) Mourey recommends coating the objects with borax, and heating to a temperature just sufficient to fuse the borax.—(Dingler's Journal, vol. 97; from the Technologiste, June, 1845.)

With reference to the means of supplying the electric current, we must take into consideration not only their constancy, but also the expense and the inconvenience produced; for instance, by the nitrous fumes of Bunsen's or Grove's elements. For small objects a simple apparatus is commonly used with an animal membrane as a diaphragm, and with a solution of chloride of sodium or cyanide of potassium at the zinc pole; the object to be coated is then used as the other pole;

* I have precipitated gold with violent evolution of gas to the amount of 1 milligramme per square centimetre, and afterwards rubbed it with the finger with a piece of linen cloth, and lastly, with a wire-brush, without taking off more than $\frac{1}{12}$ of the deposited gold. Of 2 milligrammes per square centimetre, $\frac{1}{4}$ of the gold was removed by a similar procedure.

but in general a separate decomposing cell is preferable, in which the anode is of gold, &c., connected with a common Daniell's battery. The Duke Max Von Leuchtenberg, whose laboratory for galvanic gilding is not surpassed by any other, (the Elkington's operate principally with silver,) uses plates of iron and coke charged with sulphuric acid, and the sulphate of iron produced covers the expense of maintaining the battery.—(Dingler's Journal, vol. 97, from Technologiste, August, 1845.) These batteries are only charged on Mondays, and then used, with occasional additions, day and night until Saturday, being employed at night to decompose the exhausted gold solutions, as gold anodes are not employed, they being considered dead capital and a temptation to the workmen. The gold solutions, are prepared in the laboratory in the following manner: One part of gold is dissolved in aqua regia and evaporated to dryness, a solution of one part of caustic potassa is added, the mixture heated and then filtered. The Duke considers those solutions best which contain per decilitre 1 to 0.25 grammes of gold. The extent of this establishment may be imagined when we learn that (Dingler's Journal, vol. 105, from Bulletin's de l'Academié de St. Petersbourg, No. 130,) three wooden vessels lined with India-rubber held 5,500 litres of gold solution containing about 80 pounds of gold, and that sometimes in one month 60 pounds were precipitated, as when 204 pairs of copper capitals and bases for St. Isaac's church were gilded; the total weight of these was 7,200 "pud," of 16 kilogrammes, and the surface to be gilded was about 1,300 square metres. During three years 280 kilogrammes of gold were used; eight elements were usually employed as a single pair, but when the solutions were nearly exhausted they were combined as a double-paired battery, or the size of the anode was increased. If the current was too strong, so that gas appeared at the kathode, or the object became dark colored, the surface to be gilded was sometimes increased by adding other objects. As soon as the precipitate appeared "matt,' the articles were taken out and rubbed with the wire-brush, and this was repeated three times in order to obtain a sufficient gilding.

The application of magneto-electrical machines appears to offer considerable advantages for operations on a large scale. It seems that Sturgeon was the first to use them, but Woolrich first secured a patent for their application to manufacturing purposes, which was afterwards bought by the Elkingtons.—(Dingler's Journal, vol. 105, from Bulletin de St. Petersbourg, No. 130.) The latter had a machine constructed for their manufactory of German silver ware, which daily precipitated seven Russian pounds of silver. It consisted of eight horse-shoe magnets, each of twelve steel plates, two and a half inches wide, and together four inches thick. Their length from the pole to the vertex of the arch was two and a half feet, and the arms were six inches apart. The iron cores of the armatures were six inches long, two and a half inches thick, and placed radially upon a wheel of two and a half feet in diameter, towards which the magnets were also radially directed. The wheel made 700 revolutions in a minute, and the current deposited sixteen to twenty ounces of silver in an hour.*

[*The use of this machine has been discontinued, as it was not found as advantageous as was originally supposed. G. C. S.]

In the heavy work of the Duke of Leuchtenberg the quantity of gold precipitated was determined by chemical analysis. One decilitre of the liquor was taken out of the gauged vessel before and after the gilding, and examined; very convenient methods of analysis were contrived and an account of them published.—(Dingler's Journal, vol. 99, from Bulletin Scient. Figur. de St. Petersbourg.) It is evident that, in this case, only platinum anodes could be used. Small objects were weighed before and after the gilding. Both methods are unsuitable for the common gilder, and he can only judge of the strength of the gilding by the commencement of a "matt" appearance on the polished places. A compass inserted in the circuit would enable any one, after a few trials, to determine approximately the quantity of gold precipitated in a minute, even if it were not a tangent compass. At any rate this would always reliably indicate the state of the current, while the workman now has no means whatever of ascertaining when it is growing weaker, and only knows by the evolution of gas and the darkening of the color when it is too strong.

Frankenstein introduced a new method of gilding, by which the piece to be gilded is immersed in contact with zinc. The zinc is also gilded or silvered, and the quantity of the precipitate is, according to Fehling, (Dingler's Journal, vol. 78,) nearly proportional to the time. The temperature is raised to 60° R., and the object must be taken out and cleaned every ten or twenty minutes. Frankenstein recommends for the gold solution six parts of prussiate of potash, four of carbonate of potassa, ten of water, and one of chloride of gold; and for silver five parts of prussiate of potash, five carbonate of potassa, two common salt, five aqua ammonia, and one chloride of silver. The liquid should be boiled for a half to three-quarters of an hour and then decanted. This method has been frequently adopted by manufacturers; they use, however, the common solution of gold in cyanide of potassium, adding a small quantity of caustic potassa or soda and wind annealed brass wire loosely around small objects, such as spoons, &c. In this manner Frankenstein (Dingler's Journal, vol. 90) gilded the cross and ball of a steeple in parts, and precipitated twenty-five ducats upon a surface of fifty square feet, each piece being immersed three or four times for five to ten minutes. The film of gold obtained by this treatment was matt, which is always the case when as much as half a ducat is precipitated upon a square foot. Such a gilding may, according to the above mentioned experiments of Dumas, be considered equal to a good fire gilding.*

Becquerel (Dingler's Journal, vol. 92, Comptes Rendus, March, 1844, No. 2) has made numerous experiments on the precipitation of metals from their solutions upon other metals, even upon zinc, in which latter case he ascribed the precipitation to the galvanic currents produced by the impurities in commercial zinc. He could only, as a general rule, obtain adherent metallic deposits by contact with zinc, and when the metallic salt to be precipitated was combined with an alkali to form a double salt as nearly as possible neutral. In acid

* By the use of brass wire with a piece of zinc at the end the gilding becomes reddish in color, probably from the copper dissolved out from the brass. I have gilded iron in this way without previous coppering.

liquids no adherent deposits could be produced even with the use of separate decomposing cells.

In conclusion, it may also be mentioned that the attempt has been made to gild silken threads and tissues without diminishing the flexibility and strength of the goods; *the Prussian Gewerbe Verein* has offered a premium for such a process, but, as far as I know, no one has yet been successful.

§ 183. *Etching by galvanism.*—It seems that Spencer first took up this idea; he procured a patent for his process in August, 1840. The plate to be etched served as the anode, and was placed in a cell separated by a porous diaphragm from the opposite copper plate. With the copper plate acting as the kathode, sulphate of copper was always used, but with the plate to be etched different liquids were employed according to the nature of the metal.—(Dingler's Journal, vol. 80.) For copper dilute sulphuric acid was employed, but it does not seem that this process was ever found practically useful, since, according to Hasse, (Dingler's Journal, vol. 84, from the Verhandlungen des Vereins für Beförderung des Gewerbfleisses in Preussen, 1841, 5,) the etching always proceeds more rapidly towards the border than in the middle, and the same difficulty also occurs around such places as had been stopped out after having been etched deep enough. Grove (Dingler's Journal, vol. 82, from Philosophical Magazine, September, 1841) etched daguerreotype plates in the following manner: He used one of his elements with plates of the same size as that to be etched, placed the latter in a wooden frame, at a distance of 0.2 inches from a Smee's platinized platinum plate, and immersed it for 20 to 30 seconds in dilute muriatic acid, the connection with the element having been previously made. The daguerreotype plate was previously varnished with shellac around its border and on the back, and after the etching was carefully washed with aqua ammonia by means of a little pad of cotton, then well rinsed in pure water and dried. Although the finest lines had disappeared, still the plate gave good impressions. Grove thinks it especially adapted for taking electrotype copies which may be used for printing.

About the same time Steinheil, in Munich, and Fizeau, in Paris, also made attempts to etch daguerreotype plates. Fizeau's plates bore 30 to 40 impressions.

§ 184. *Nobili's rings.*—Nobili's experiments are older than the period to which my report is limited, and some of them date back as far as the year 1826. He experimented with many liquids, and upon plates of very different metals at the positive as well as at the negative pole. An account of these experiments is to be found in Pogg. Ann., vol. 10, and also in Dingler's Journal, vol. 94.

Nobili obtained the most brilliant colors from acetate of lead by placing the metallic plate at the positive pole and immersing the negative pole in liquid liquid. It is said that he also succeeded in producing mono-chromatic coatings, but that he never communicated the process to any one. Böttger obtained such coatings upon platinum from different proto salts of manganese (hippurates, acetates, succinates.) The platinum plate connected with the positive pole was laid in the solution, and the negative pole, which was also a circular plate, was

placed opposite to it. But it is not necessary that the negative pole should end in a plate. With a simple platinum wire the same salts furnish nomo-chromatic tints, which successively change, so that the experiment may be interrupted with any color desired. Only chloride of manganese gave colored rings like those obtained with acetate of lead. Böttger used solutions of 1 part of the salt in 12 to 16 parts of water, and employed a battery of 4 elements. He gives the following as the best mode of performing the experiment: a short platinum wire is to be soldered to the centre of a circular platinum plate, a glass dish is perforated in the middle, and the plate placed in it, so that the wire passes through a cork in the hole, and projects a little from the bottom of the dish. The glass dish is then placed upon a board in which a mercury cup is inserted, and into this dips the wire from the dish, while another wire passing through the board connects the mercury with the positive pole.

Elsner (Gewerbeblatt für Sachsen, 1842, No. 29; Dingler's Journal, vol. 85) applied Fechner's simple process to produce Nobili's rings upon steel plates. He poured acid acetate of copper (solution of verdigris in vinegar) over the plates, touched them in different places with a zinc rod, dried them and heated them over a spirit lamp, when different colors are successively developed, and the operation may be interrupted as soon as the desired tint is obtained. The theoretical reflections appended to the memoir do not appear to be based upon quite clear ideas, and are therefore better omitted in this place.

Becquerel (Comptes Rendus, February, 1844, No. 6; Dingler's Journal, vol. 91) repeated the experiments of Nobili in various ways, and obtained particularly beautiful colors upon different metals when used as positive poles in a solution of litharge in caustic potassa, while the negative pole was a platinum wire or plate. Lead is precipitated on the platinum, and on the positive pole peroxide of lead, by which these splendid colors are produced. Becquerel boiled finely powdered litharge for a long time in a solution of caustic potassa of 20° to 22° Beaumé, and used six Daniell's elements for his battery. But the colors are readily developed with much weaker solutions and with fewer elements when small platinum plates are employed. It is only with very fine platinum wires, covered with glass except at the points, that more elements are necessary, but the rings thus obtained are more perfect in form.

Becquerel is said to have produced uniform shades by employing many wires projecting from the glass tube and radiating toward the positive metallic plate. These colors resist very well when rubbed with the finer polishing powders, such as English rouge, but are changed by being exposed to the action of acid or ammoniacal vapors. As a protection against this action, Becquerel recommends the application of two coatings of a varnish, made as follows: $\frac{1}{2}$ litre linseed oil, 4 to 8 grammes finely powdered litharge, and 2 grammes sulphate of zinc, are moderately heated for several hours and then filtered. But Becquerel himself admits that some of the colors are injured by this treatment. This is also the case with shellac varnish. Becquerel has experimented with gold, copper, silver, (which gave no fine colors,) platinum, German silver, and steel; even bell-metal gave good results, but tin required

a previous, although very thin, gilding. The younger Becquerel (Ann. de Chim. and de Phys., March, 1845: Dingler's Journal, vol. 96) directed attention to the fact that the order of the colors thus obtained corresponds to that obtained with transmitted light, and also maintained that the thickness of the layers decreases from the centre of the rings in the inverse ratio of the radii. Zur Nedden (Dingler's Journal, vol. 94) attempted to refute the opinion that the colors were produced by "thin plates" at all, and thinks that they arise from the colors of the precipitated combinations and of the metals themselves. But without disputing the influence of these two causes upon the shade of individual colors, there cannot be the least doubt that their order, as obtained, for instance, upon German silver is exactly the same as that obtained from a wedge-shaped plate of gypsum when the mirrors of the polarizing apparatus reflect the light in planes at right angles to each other.

The above mentioned assertion of Edmund Becquerel, that the thickness of the layers is in the inverse ratio of the radii of the rings, based upon theoretical consideretions and confirmed by measurement on two selected plates, was opposed by Du Bois, Reymond and Benz, (Pogg. Ann., vol. 71.) The former deduced, from accurate theoretical investigations, the law that the thickness of the stratum precipitated by galvanic currents at different distances from the negative point must be inversely as the cubes of the radii, and Benz proved by experiments that this actually is the case. The discrepancy between these contradictory experiments is not yet explained.

The splendid colors obtained in the manner indicated are already used in the arts for covering table bells, cups, and other small ware of brass plate. The solutions of oxide of lead used for this purpose is prepared in the following manner: One part of caustic potassa is dissolved in 5-6 water, and boiled with finely ground litharge in excess for half an hour in an earthenware vessel, being well stirred all the time. The solution is then filtered and preserved in a well closed vessel. For use, the liquid is poured into a vessel of lead or brass large enough to hold conveniently the object to be coated, which is connected with the positive pole of a Daniell's battery of 3 pairs, and immersed in the lead solution, when the negative pole is connected with the outside of the vessel. The strength of the current must be regulated experimentally by means of the charging fluids, so that the formation of the rings, of which usually only the first two systems are well developed, proceeds somewhat slowly, by which means the current may with more precision be interrupted just when the desired shade is obtained. Brass requires some modifications in the process, as Becquerel had previously noticed; objects of this metal must be gradually immersed into the solution with the sharp edge foremost, the circuit having been previously closed. All the objects must be well cleaned with Tripoli or English rouge, and should not afterwards be touched with the fingers; varnish is not usually employed.

§ 185. *Obtaining metals from their ores by means of galvanism.*—Becquerel devoted especial attention to the solution of this problem; but notwithstanding the promise of his first reports, and the considerable

amount of aid he seems to have received, no really important result has been obtained. A report in the Comptes Rendus of 1840 (Dingler's Journal, vol. 77) sets forth in brilliant colors the advantages of the new process, but, though a great many electrical reactions are described, very little information can be found on the subject in question, except that the method has to be modified according to the nature of the ores, and that a slight previous roasting is required if the ores do not contain metallic silver or sulphuret of silver ; for it was to the ores of this metal that his first experiments were confined, although he intended to take up the other metals in their turn. Becquerel, by irrelevant digressions, makes it very difficult to understand his discussions, and taxes the patience of the reader.

In a later report in the Comptes Rendus of 1842, No. 4, (Dingler's Journal, vol. 84,) Becquerel gives an account of his experiments in separating gold. His process is as follows: The ore is dissolved in muriatic acid, and another muriatic solution is prepared containing all the other metals in the same proportion in which they are contained in the ore. These two solutions are brought to the same density, and these serve as the exciting liquids of a simple battery, that containing the gold being placed with a platinum plate in the inner vessel, which has a clay stopper in its bottom, and the other in the outer vessel with a copper plate. The circuit must be kept closed until all the gold is deposited upon the platinum, whose increase of weight indicates the quantity of gold precipitated. But it seems that in the use of this process on a large scale the subsequent separation of the gold from the platinum might present new difficulties, in addition to those which would be incurred by an imperfect exhaustion of the solution of gold.

A similar proposition had before been made by a Mr. Byer, (Dingler's Journal, vol. 80; from Mechanic's Magazine, No. 911,) and its priority disputed by Martin Roberts, but rather with the view of obtaining a quantitative determination of ores after their qualitative analysis. The ore properly prepared was to be dissolved, and the solution used in a simple battery as one of the liquids, diluted muriatic or sulphuric acid being used for the other. The metals to be employed should be two which are nearest alike in affinity, and the metal used as the negative pole should be the same as the one to be precipitated. If, for instance, iron is contained in the solution, iron and zinc must be taken, a known portion of the dissolved ore put in contact with the weighed iron plate and the circuit kept closed until the exhaustion of the solution of iron, which metal only, it is said, will be deposited upon the iron plate. If there is copper in the solution, copper and iron should be used ; and in this manner different metals may successively be separated, and their quantity determined by the increase of weight of the negative metals.

In the Comptes Rendus of May, 1846, (Dingler's Journal, vol. 101,) Becquerel indicates a process for decomposing silver ores which are insoluble in water. They are placed with a solution of common salt in a glass, with the indispensable clay stopper in its bottom, and this is set in another glass also containing the same solution, into which zinc is immersed connected with the ore by means of a silver wire.

The sodium, liberated by the decomposition of the chloride of sodium, combines with the chlorine of the chloride of silver, and thus the silver is reduced and obtained in a more or less porous condition. It is the more compact as the current is weaker, *i. e.*, as the solution of salt is more dilute, and as the aperture closed with the clay stopper is smaller. But the action had, in all cases, to be continued for several weeks, in order to reduce only a moderate quantity of silver. But here, too, Becquerel was not the first to describe this, or, at least, a very similar method. The instrument maker and assayer, Oechsle, in Pfarzheim, had, in 1842, already published in Dingler's Journal, vol. 86, the following method of reducing chloride of silver: The chloride is worked into a thick paste with a saturated solution of common salt, and then put into a porous cell, which is set in a vessel containing sulphuric acid diluted to $\frac{1}{20}$; the zinc is placed in this vessel, while platinum or silver is used with the chloride of silver, and the circuit is kept closed until the grayish sediment of silver, when stirred no longer, shows any milky streaks; it is then well washed and dried. A similar process is again described in Poggendorf's Annals, 1848, No. 11.

James Napier (Dingler's Journal, vol. 97, from Repertory of Patent Inventions, July, 1845,) proposes to reduce the metals in a fused state, and this he does by putting the roasted metallic sulphurets together with the proper flux in a black lead crucible, which, with the exception of the bottom, had been coated inside with clay. When all is fused he places upon the mass an iron plate riveted to a rod of the same metal, another iron rod is to be placed in contact with the outer surface of the crucible, and both rods connected with the proper poles of a battery.

William Ritchie, in 1844, patented a process for obtaining metallic copper, which is very similar to that described by Dechaud and Gautier de Claubry in the Comptes Rendus of 1845, (Dingler's Journal, vol. 97.) It consists essentially in changing the sulphuret into sulphate of copper, which is then decomposed by galvanism. The apparatus for this purpose consists of a number of large troughs with several divisions, each of which is again divided into two parts by a pasteboard diaphragm. One of these parts contains sulphate of copper and a plate of lead, or rather of sheet iron coated with lead; the other contains sulphate of iron and a cast iron plate, which, together, form a simple battery. The inventors think that they will be able for every square metre of plate to reduce 1 kilogramme of copper in twenty-four hours, and that of the whole quantity of copper in the solution they can obtain 50 per cent. in plates, 25 per cent. granulated, and the remainder in a finely divided state. The apparatus is supplied from large reservoirs containing the liquids in the proper state of concentration, while the exhausted solution of sulphate of copper, as well as the saturated solution of the sulphate of iron, are, at the same time, carried off. Accurate statements as to the advantages of this process are still wanting.

[Since the date of the publication of Müller's report the art of electrotyping has been greatly developed. The general principles of this art, so well shown by our author, are so universally applicable that

a full quotation of later authors, which we had at one time intended, would be in most cases but a repetition of what has already been said.

The reproduction of works of art by this method has been amply illustrated in the late European industrial exhibitions. The simplest and lowest application which has, however, had the widest employment is the following: Small figures, generally intended for parlor ornaments, are cast in zinc, and coated externally with copper or some alloy of copper. In this process the electrotype is not properly applied to the reproduction of the figure, but simply to the formation of a copper surface upon a cast already made. Another plan is to precipitate a copper shell upon a fusible metal cast, which is afterwards partly melted out, leaving a very light but sufficiently solid figure. By these methods the now common "bronze" ornaments are made.

Fine works are actual reproductions of the surface of a mould by methods already explained, but those requiring more care and attention bear a correspondingly higher value.

But it is in its applications to printing that this art has had the greatest influence. Detailed descriptions of the mode of operation are wanting, but as to their extent we may form some idea from the statement of Lieutenant E. B. Hunt, U. S. A., (in the Report of Professor A. D. Bache, the Superintendent of the United States Coast Survey, for 1854, p. 208, Appendix,) who, in speaking of the capacity of printing from relief, says that "is well illustrated by the 135,000 impressions regularly worked from the pages of Harper's Magazine. Each page of this publication is electrotyped, a copper film coating type and wood-cuts alike, and type metal is melted into the back of the copper shell to give it the required thickness; thus both type and wood-cuts are converted into a relief copper plate, from which the prints are worked off."

The perfect and certain reproduction on the large scale of the finest specimens of the engraver's art is the most remarkable extension of the electrotype. Of this we have the best account in the anual reports of the United States Coast Survey.

Electrotype operations of the United States Coast Survey, Mathiot's Improvements.—Although fine copper plate engravings have been multiplied in this manner by the English ordnance survey, by the French "Dépôt de la Guerre," by the royal establishment at Vienna and elsewhere, that we are authorized in dwelling upon the methods of our own national establishment is shown by the passage from a letter of Colonel Blondell, director of the "Dépôt de la Guerre," who says of the account of the operations of the United States Coast Survey: "The perusal of the memoir has convinced me at once of the superiority of the electrotype methods which are used in the United States. The reproduction in less than three days of a plate of large size is an improvement of the highest importance."

We have drawn our information from the annual reports of the Coast Survey, but have also verified this by personal inspection, under the favor of Professor A. D. Bache, the Superintendent, and of Mr. George Mathiot, who has charge of the electrotype department.

It should be premised that the maps of this establishment are engraved in the highest style of art attainable under a minute division

of labor in each kind of work. The fineness of the work at once rendered necessary some economical reproduction of the plates, in order that the maps might be sold at a low price, which would have been impossible if a new engraving had to be made when each plate wore out. The first attempts brought to light a most serious difficulty, the copper deposit was liable to adhere, involving the partial destruction of the costly original.

By an ingenious process of reasoning Mr. Mathiot was led to the employment of iodine to prevent the adhesion of the deposit to the matrix. It was, however, found difficult to apply the iodine uniformly. The plates were next, previously silvered, and then washed with an alcoholic solution of iodine, which effectually produced the desired result. It was soon found that when the iodized plate had been exposed to the action of light the separation was most easy and certain, and this is the plan now uniformly adopted with unfailing success. For the largest plates a solution of one grain of iodine in twenty thousand grains of strong alcohol is used.

"To test the effect of the chemical method of preventing adhesion on the sharpness of the engraved lines an engraving was seven times successively transferred from plate to plate, when the closest inspection failed to show any inferiority of impressions from the last plate as compared with those from the first."—(Coast Survey Report for 1851, p. 544.)

The next matter of importance was to diminish the time and consequently the expense of depositing large plates without impairing the ductility of the metal. Previously the best results attained had been the deposit of one pound of copper in twenty-four hours on a plate of eight square feet, and this only under extraordinary precautions.

The desired end was attained by a succession of improvements. In the first place the platinized silver plates of Smee's battery, the one which Mr. Mathiot seems to prefer, were liable to a coating of impurities derived from the zinc, (zinc itself deposited upon them?) this was found to be removed readily by immersion in a solution of chloride of iron. In the next place, in order to bring the plates of the battery nearer together, to reduce the resistance, it was found necessary to have silver more flat and true than could be made by hammering. Such plates were finally made by electrotype deposits, by means which we cannot now stop to describe, but which insured certainty and uniformity in their manufacture. After these improvements Mr. Mathiot was able so to proportion the size and number of the elements of the battery as to attain the required rapidity of deposit without sacrifice of the ductility of the metal. Finally, by a simple contrivance for maintaining a constant temperature above 100° Fahr. in the decomposing cell, the rapidity of the deposit and the quality of the metal were still more improved, with the further advantage of keeping the saturation of the copper fluid more uniform throughout its mass.

In order to maintain the exceedingly fine surface required by the delicate work on these plates, it was found necessary to make the first immersion in a vertical position, so that impurities in the solution could not rest upon the plate upon which the deposit was forming. To save the trouble and time required for drawing off the fluid and

filtering off these impurities, the following simple and efficient plan was devised: A bag of fine cotton is placed over a light wooden frame which keeps it distended, this is gradually immersed in the solution in the vat, and when it reaches the bottom it is found to contain a clear filtered solution into which the plates may at once be immersed.

After the first day the plates are placed in another vat in a horizontal position which is more favorable than a vertical one. The opposed plate when loaded with impurities is removed and a fresh one substituted, the increase of the deposits being estimated from the loss of the opposed plates.

The attentive reader of this work will have seen the importance of a galvanometer of some kind for ascertaining with precision the manner in which the work is proceeding in the decomposing cell. It is not always convenient to place such an instrument in the main circuit, and Mr. Mathiot has arranged for this purpose what he calls a "branch circuit galvanometer," which is in fact a galvanometer placed in a portion of the current led off by a smaller wire so that the instrument may have any desired position, an arrangement similar to that already noticed in the first part of this report. If the portion of the whole current thus diverted through the side conductor be small, the increase of resistance due to the greater length of the wire will be but a small matter when compared with the whole. It is an easy thing to determine by a few weighings the rate of deposition due to any particular angle of deviation in the needle.—(Coast Survey Report for 1855.)

By these well contrived arrangements electrotype copies of the most delicate engravings are literally *manufactured* with undeviating certainty. The routine is so well established that an ordinary workman can, when once well instructed, proceed without risk in the performance of delicate operations, which at one time might be attended with hazard in the hands of the most skilful. It must of course be understood that we have not entered into all of the minutiæ of the operations, for which we must refer to the reports of the Coast Survey. The object has been to show what we consider a notable instance of the influence of a thorough organization in carrying out in practice the most refined details. The application of this art to quite different objects would necessarily involve a departure from the precise methods just described. But the scientific basis, as laid down in the report of Müller, will in all cases be applicable. Many ingenious devices for attaining special ends may be requisite, but they must all be in obedience to the known laws of electricity.

Before concluding we must refer to one or two additional improvements in the reproduction of copies of engraved maps which have originated in the same quarter.

At an early period it was found a very desirable matter to add together several detached maps or to correct or improve certain portions of a finished engraving. It is obvious that this could be accomplished by the nice adjustment of the parts which were to be the components of the new map. But this required very accurate and skilful mechanical manipulation, not without some risk to the engraved surface. The plan devised by Mr. Mathiot for overcoming these difficulties consists in "taking from the plates to be joined electrotype casts weighing not

more than three or four ounces to the square foot. These being cut in any required form with a pair of scissors, require merely to be cemented, each in its proper place, on a blank plate coated thinly with shoemakers' wax." The facility of combination thus introduced has greatly abridged the time and labor expended upon this species of work.—(Coast Survey Report of 1855.)

A still further extension of this idea is noticed in the Coast Survey Report of 1857, p. 189. "It is now practically ascertained that thin electrotypes are all that is necessary; the stiffness requisite to print from being given by stretching them on steel plates having a smooth surface and cut to the proper size." Mr. Mathiot also adds as follows: "The working of the thin electrotypes has suggested to me the idea of using these plates on a circular bed or roller, and gaining thereby the great advantage of cylinder printing for flat plates." The improvement of copper plate printing by steam machinery is thus suggested as highly probable.—G. C. S.]

METEOROLOGY.

ESTIMATE OF THE COST OF ESTABLISHING METEOROLOGICAL STATIONS IN THE DIFFERENT STATES.

Estimate of cost per station for preparing and publishing the abstracts in the form adopted by the Smithsonian Institution, not including the velocity of the wind.

Preparation of the abstracts per station*	$8 00
Publishing the same on the supposition that there are 500 stations in the whole, and allowing $2 50 per page 8vo., of the form of the Smithsonian tables for 1855, for composition, 50 cents per token for press work, $7 50 per ream for paper, and a suitable amount for contingencies	6 00

The following statement shows the number of stations required for each State to carry out the above scheme, (see page 33,) and the estimated cost:

States and Territories.	No. of stations.	Estimated cost.	States and Territories.	No. of stations.	Estimated cost.
Maine	10	$360 00	Delaware	1	$36 00
New Hampshire	2	72 00	Maryland	3	108 00
Vermont	2	72 00	Virginia	17	612 00
Massachusetts	2	72 00	North Carolina	13	468 00
Rhode Island and Connecticut	2	72 00	South Carolina	8	288 00
			Georgia	16	576 00
New York	13	468 00	Florida	16	576 00
New Jersey	2	72 00	Alabama	14	504 00
Pennsylvania	13	468 00	Minnesota	39	1,404 00
Mississippi	13	468 00	Texas	90	3,240 00
Louisiana	11	396 00	Arkansas	15	540 00
Tennessee	12	432 00	California	52	1,872 00
Kentucky	10	360 00	Indian Territory	52	1,872 00
Ohio	11	396 00	Kansas	35	1,260 00
Michigan	16	576 00	Nebraska	101	3,636 00
Indiana	9	324 00	New Mexico	59	2,124 00
Illinois	15	540 00	Oregon	53	1,908 00
Missouri	18	648 00	Utah	52	1,872 00
Wisconsin	16	576 00	Washington Territory	33	1,188 00
Iowa	14	504 00			
Total				860	24,360 00

*About 70 per cent. of this work may be done by the observers, and if correctly this item of cost will be proportionally reduced. The estimate is some 18 per cent. below the actual cost, the advantage of having the work done under the direction of the Smithsonian Institution being supposed to be sufficient to make up for the deficiency.

METEOROLOGICAL STATIONS CONNECTED WITH THE SENIOR COUNTY GRAMMAR SCHOOLS.

[From the Annual School Report for 1858.]

1. *Circular to the county councils and to the boards of senior county grammar schools in Upper Canada.*

GENTLEMEN: I have the honor to inform you that the necessary instruments for making meteorological observations at each of the senior county grammar schools in Upper Canada have been procured by the chief superintendent of education, and are now ready for distribution by this department.

The section of the grammar school law authorizing the establishment of these meteorological stations in connexion with the senior county grammar schools of Upper Canada is as follows:

"Whereas it is desirable at seminaries and places of education to direct attention to natural phenomena, and to encourage habits of observation; and whereas a better knowledge of the climate and meteorology of Canada will be serviceable to agriculture and other pursuits, and be of value to scientific inquirers:

"*Be it therefore enacted*, That it shall be part of the duty of the master of every senior county grammar school to make the requisite observations for keeping, and to keep, a meteorological journal, embracing such observations, and kept according to such form, as shall from time to time be directed by the Council of Public Instruction; and all such journals or abstracts of them shall be presented annually by the chief superintendent of schools to the governor with his annual report.

"Every senior county grammar school shall, on or before the last day of November, one thousand eight hundred and fifty-four, be provided, at the expense of the county municipality, with the following instruments:

"One barometer; one thermometer for the temperature of the air; one Daniels' hygrometer, or other instrument for showing the dew-point; one rain-gauge and measure; one wind-vane.

"And it shall be the duty of the chief superintendent of schools to procure these instruments at the request and expense of the municipal council of any county, and to furnish the master of the senior county grammar school with a book for registering observations, and with forms for abstract thereof, to be transmitted to the chief superintendent by such master, who shall certify that the observations required have been made with due care and regularity."

The delay which has occurred in providing these instruments has been unavoidable. Those first selected in the United States were found to be unsuitable; and upon consultation with Colonel Lefroy, so long and favorably known in connexion with this department, improvements, which experience in this climate had suggested, were adopted, and a range as low as 35° and 40° below zero was given to the thermometers.

The instruments, when ready, were all tested by James Glaisher, esq., and their variations recorded. They were also examined and approved by Colonel Lefroy. In addition, the chief superintendent

considered it important to subject them to a winter's test at the Provincial Magnetical Observatory, Toronto, before sending them out, and to compare and note any variations which might be caused by exposure to extreme cold.

The various instruments and books which are now ready for distribution are as follows:

One barometer, either standard or one of a second quality.

A self-registering maximum thermometer.

A self-registering minimum thermometer.

A wet and dry bulb thermometer.

A rain-gauge and graduated measuring glass.

A copy of the Official Instructions and Directions for making and recording Observations.

Daily register book, containing printed forms, and adapted for the observations of one complete year.

Monthly and annual abstract book, containing printed forms, and adapted for the observations of one complete year.

Blank book for extraordinary records.

Map of the Stars, four tables, and synopsis, reprinted from the Instructions and mounted for convenient reference.

A copy of Drew's Practical Meteorology.

A copy of Coffin's [Smithsonian] Hygrometrical Tables, bound up with the Instructions.

(A wind-vane is not sent. It can easily be constructed at the station.)

The cost of these instruments and books, including packing, &c., will be $140, one-half of which will be borne by this department and the other half by the county to which the instruments are sent. Where desirable, an officer will be despatched from the department with the instruments to insure safety in their carriage and to assist in fitting them up at the proposed station. Should you desire the instruments to be sent to your grammar school, I will thank you to notify me at your earliest convenience, so that the necessary arrangements for that purpose may be made, and transmit the required amount ($70) with the enclosed form duly filled up. Where, instead of the standard barometer, a barometer of the second quality is selected, the price of the set of instruments, &c., is $110, only one-half of which ($55) need be sent.

The instructions for taking and recording observations, which have been approved by the Council of Public Instruction, have been carefully prepared by the director of the Provincial Observatory, and are sufficiently minute and explicit to enable the head master of the grammar school to make the necessary observations without much trouble. Attention and patience will be indispensable at first, but time and practice will soon insure regularity and accuracy in the observer.

In order to afford time for practice, it is suggested that no observations be recorded in the books sent until the 1st of January next. A sufficient supply of unbound sheets will accompany each set of instruments to enable the head master to record his observations on them until that time. A form of monthly returns will also be sent by mail, in which can be recorded each month's observations. These

monthly reports should be regularly transmitted to the chief superintendent, as required by law.

Of the great practical importance, to a new and but partially settled country, of establishing (thus early in its history, and before its physical condition is materially changed) a complete and comprehensive system of meteorological observations, I need scarcely remark, as the subject will no doubt receive your attentive consideration. The department will rely upon your cordial co-operation in the matter.

Every enlightened country in Europe is now more or less engaged in prosecuting inquiries in this particular branch of science. In the other parts of her Majesty's dominions, and in the United States, meteorological stations have been long since established. Although the science is yet comparatively in its infancy, yet from the aggregate of facts which have already been collected at various points and in different countries, truths of highest value and importance in scientific research have been unfolded, unsettled theories have been tested, and questions relating to physical phenomena, which had long remained among the sealed mysteries of nature, have been satisfactorily solved.

I have the honor to be, gentlemen, your very obedient servant,

J. GEORGE HODGINS,
Deputy Superintendent.

EDUCATION OFFICE, *Toronto, September* 25, 1857.

2. *Meteorological Stations Established.*

During the present year the following meteorological stations have been established at the senior county grammar schools in Upper Canada:

1, Port Sarnia; 2, Chatham; 3, Guelph; 4, Hamilton; 5, Niagara; 6, Milton; 7, Barrie; 8, Whitby; 9, Belleville; 10, Pictou; 11, Perth; 12, Cornwall; 13, L'Original, (instruments purchased but not yet sent for.)

Each of these twelve stations has been visited by an officer of this department who, in addition to fixing the locality, position of instruments, &c., has given practical instructions in the use of the instruments with which the stations have been provided. It was not thought necessary to supply wind-vanes, as they are easily constructed at the stations. Instructions, however, were given for making approximate observations of the direction and velocity of the wind.

Each of the stations has also been supplied with a sufficient quantity of sheets of the various forms and abstracts for practice, previous to making entries in the registers.

The daily register contains a sufficient number of the two forms, A and B, for a year's observation, as follows:

Form A contains on each of its pages the following headings, viz: "Barometer corrected at 32° Fah.; Gaseous pressure; Temperature of air corrected; Wet bulb thermometer corrected; Difference of dry and wet bulb; Elasticity or tension of vapor; Humidity; Direction and velocity of wind; Appearance of sky; Class and arrangement of clouds; Amount of cloudiness; Clouds in motion—Class, Elevation, Direction, Form, and Velocity; Aurora; General remarks." These observations are required to be made three times a day, viz: at 7 a. m., 1 p. m., and 9 p. m.

Form B contains blanks for one month's observations on one page, the columns for which are, "Day of the month; Self-registering maximum and minimum thermometers; Daily range of temperature; Rain, Began at, Ended at, Total duration; Cubic inches in gauge; Depth in inches; Snow, Began at, Ended at, Total duration; Depth in inches; Total depth of rain and melted snow; Remarks."

Full instructions having been given, the observers, after a little practice, were required, in accordance with the act and regulations, to transmit monthly abstracts of their observations to the educational department, two forms for which were supplied as follows:

Form C, which is a condensation of forms A and B, contains columns for the corrected observations, and the daily as well as monthly means.

Form D includes the "highest, lowest, and monthly range of barometer; also, the great ranges within twenty-four hours; the dates and total number of rainy days, snowy days, foggy days, storms of wind, frosts; columns for four classes of auroras: sky unfavorable, observations doubtful; sky unfavorable, observations impossible; sky favorable, none seen; the highest, lowest, and monthly range of temperature; the greatest and least daily range; the mean temperature of the warmest and coldest days; lightning, thunder, hail, or rain; meteors and optical phenomena; general remarks."

These abstracts are required to be certified as true copies of the originals, and the observations as having been made with due regularity, as required by law.

The annexed table will show how far the observers have succeeded in accomplishing the objects contemplated by the act:

Meteorological station.	When established in 1858.	No. monthly abstracts received at editor's office.	CHARACTER OF ABSTRACTS RECEIVED.		
			Well prepared.	Middlingly.	Imperfectly.
*1. Niagara	January	2		2	
*2. Hamilton	do	3		3	
3. Belleville	do	10	‡8	2	
4. Barrie	do	8	‡8		
5. Chatham	do	4			4
6. Port Sarnia	do	7	‡7		
*7. Milton	February	3			3
†8. Cornwall	do				
9. Guelph	September				
10. Whitby	do				
11. Perth	October				
12. Pictou	do				
Total		37	23	7	7

* No reports have been received from Niagara for several months, nor from Hamilton or Milton for some time; but the omission at these two stations was owing to a change of masters.

† The master at Cornwall having tendered his resignation, the instructions were not given till October.

‡ Names of observers from whom well prepared abstracts have been received: At Belleville, Alexander Burdon; at Barrie, Rev. W. F. Checkley, A. B.; and at Port Sarnia, Rev. G. J. R. Salter, B. A. The observations taken at Barrie have been regularly published in the local papers.

[Correspondence.]

THE EARTHQUAKE OF 1811 AT NEW MADRID, MISSOURI.

(*From the narrative of an eye-witness.*)

BY TIMOTHY DUDLEY, OF JACKSONVILLE, ILLINOIS.

I am indebted to James Ritchie, esq., of Jerseyville, Illinois, for the facts embodied in this article, who was living with his family at the time of this earthquake in the vicinity of its most violent commotions, and those scenes were so vividly impressed upon his mind that, after a half century has nearly passed away, they are as fresh and vivid as though they transpired yesterday:

On the west bank of the Mississippi river, sixty-five miles below the mouth of the Ohio, by the windings of the river, and about twenty miles in a direct line, stands an old Spanish town called New Madrid. The southern boundary line of Kentucky is the famous political line of 36° 30′ north latitude, constituting also the southern boundary line of Missouri, crossing the Mississippi river a short distance below New Madrid. Thirty miles below was an old French village called Little Prairie, and south and west of this village is a long cypress swamp extending north and south a distance of one hundred and twenty miles, and in breadth east and west twenty-five or thirty miles, which was called fifty years since the St. Francis swamps.

I have been thus particular in locating these old towns and lowlands from the fact that evidence is continually accumulating which goes to prove that all the commotions which have disturbed the earth's surface for the last half century in the western States have had their origin in the St. Francis swamps.

On the 16th day of December, 1811, at two o'clock in the morning, the inhabitants of New Madrid were aroused from their slumbers by a deep rumbling noise like many thunders in the distance, accompanied with a violent vibratory or oscillating movement of the earth from the southwest to the northeast, so violent at times that men, women, and children caught hold of the nearest objects to prevent falling to the ground.

It was dangerous to stay in their dwellings, for fear they might fall and bury them in their ruins; it was dangerous to be out in the open air, for large trees would be breaking off their tops by the violence of the shocks, and continually falling to the earth, or the earth itself opening in dark, yawning chasms, or fissures, and belching forth muddy water, large lumps of blue clay, coal, and sand, and when the violence of the shocks were over, moaned and slept, again gathering power for a more violent commotion.

On this day twenty-eight distinct shocks were counted, all coming from the southwest and passing to the northeast, while the fissures would run in an opposite direction, or from the northwest to the southeast.

On a small river called the Pemiseo at that time stood a mill owned by a Mr. Riddle. This river ran a southeast course, and probably

was either a tributary of the St. Francis or lost itself in those swamps. This river blew up* for a distance of nearly fifty miles, the bed entirely destroyed, the mill swallowed up in the ruins, and an orchard of ten acres of bearing apple trees, also belonging to Mr. Riddle, nearly ruined. The earth, in these explosions, would open in fissures from forty to eighty rods in length and from three to five feet in width; their depth none knew, as no one had strength of nerve sufficient to fathom them, and the sand and earth would slide in, or water run in, and soon partially fill them up.

After the earthquake had subsided there was not a perfect row of trees left in this orchard—one-half destroyed, some leaning in one direction, others directly contrary; some covered to the limbs in these chasms as they filled up, and others with their roots turned entirely out of the earth.

Large forest trees which stood in the track of these chasms would be split from root to branch, the courses of streams changed, the bottoms of lakes be pushed up from beneath and form dry land, dry land blow up, settle down, and form lakes of dark, muddy water.

Where the travelled, beaten road ran one day, on the next might be found some large fissure crossing it, half filled with muddy, torpid water. It was dangerous to travel after dark, for no one knew the changes which an hour might effect in the face of the country, and yet so general was the terror that men, women, and children fled to the highlands to avoid being engulphed in one common grave. One family, in their efforts to reach the highlands by a road they all were well acquainted with, unexpectedly came to the borders of an extensive lake; the land had sunk, and water had flowed over it or gushed up out of the earth and formed a new lake. The opposite shore they felt confident could not be far distant, and they travelled on in tepid water, from twelve to forty inches in depth, of a temperature of 100 degress, or over blood heat, at times of a warmth to be uncomfortable, for the distance of four or five miles, and reached the highlands in safety.

On the 8th of February, 1812, the day on which the severest shocks took place, the shocks seemed to go in waves, like the waves of the sea, throwing down brick chimnies level with the ground and two brick dwellings in New Madrid, and yet, with all its desolating effects, but one person was thought to have been lost in these commotions.

A family of the name of Curran were moving from New Madrid to an old French town on the Arkansas river, called the Port; had passed the St. Francis swamps and found some of their cattle missing; Le Roy, the youngest son, took an Indian poney, rode back to hunt them, and was in the swamp when the first shock took place, was never seen afterwards, and was supposed to have been lost in some of those fearful chasms.

The Port was about one hundred miles below what is now called Little Rock, and claims its settlement as far back as the settlement of

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* I have used this expression because it was so given by the narrator, and used by the people, as conveying the appearance of these scenes as they passed before them.

Philadelphia. It was about one hundred and fifty miles southwest of the swamps, and the people heard the first shocks on the 16th of December, and at the same time as the citizens of New Madrid, but the sounds and shocks came from the northeast.*

I will briefly notice some of the phenomena connected with these earthquakes, the state of the weather at the time, and the opinions which the people held in regard to their origin, or the great cause of them.

The weather was warm and smoky, and had been so for some days, not a breath of air stirring, and so thick and smoky that the Kentucky shore, one mile distant, could not be seen at all. They were in a balmy Indian summer. The morning after the first shock, as some men were crossing the Mississippi, they saw a black substance floating on the river, in strips four or five rods in breadth by twelve or fourteen rods in length, resembling soot from some immense chimney, or the cinders from some gigantic stove-pipe. It was so thick that the water could not be seen under it. On the Kentucky side of the river there empties into the Mississippi river two small streams, one called the Obine, the other the Forked Deer. Lieutenant Robinson, a recruiting officer in the United States army, visited that part of Kentucky lying between those two rivers in 1812, and states that he found numberless little mounds thrown up in the earth, and where a stick or a broken limb of a tree lay across these mounds they were all burnt in two pieces, which went to prove to the people that these commotions were caused by some internal action of fire.

In the Mississippi river, about five miles above what was then called the first Chickasaw Bluffs, but in later times Plum Point, was an island about three miles long, covered with a heavy growth of timber, which sank in one of these shocks to the tops of the trees, which made the navigation extremely dangerous in a low stage of the river.

About four miles above Paducah, on the Ohio river, on the Illinois side, on a post-oak flat, a large circular basin was formed, more than one hundred feet in diameter, by the sinking of the earth, how deep no one can tell, as the tall stately post-oaks sank below the tops of the tallest trees. The sink filled with water, and continues so to this time.

The general appearance of the country where the most violent shocks took place was fearfully changed. So many farms were ruined that our government gave to each landed proprietor a title to a section (640 acres) of land in what was then known as the Boon Lick country, on condition of proving their loss, and by relinquishing their rights in the injured lands to government.

In all grants of land to private individuals, although the laws regulating such grants may be very stringent, cunning men can be found who will find opportunity to evade these laws, and such was the case undoubtedly in many of these old grants, but the actual sufferers were

* The shocks felt in October, 1857, were the most violent in St. Louis, and seemed to come from the south or southwest. In point of fact, seldom a year passes when these shocks are not felt. Slight, indeed, they may be, as the inhabitants are so accustomed to them they pay no regard to them, and it is only when the more violent are felt, and extend beyond these earthquake regions, that any notice is taken of them.

relieved, even if some few individuls were benefitted at the expense of the general government.

This country was first settled under the Spanish government, ceded by that government to France, and by the French government, under the Emperor Napoleon, to the United States in 1803.

The Spanish government pursued a most liberal policy towards settlers to encourage emigration, every man who settled in this new country being allowed one hundred arpents, a married man and wife two hundred arpents, each male child also one hundred, each female child fifty, and twenty arpents to each slave, but in no case to exceed six hundred arpents to each family, or one square mile, an arpent being about seven-eighths of an English acre, and no single claim to be more than eighty rods in breadth fronting on the river.

The purchase took place in April, 1803, was ratified by the American Congress in December following, and all settlers from the time of the purchase in April to the ratification of the treaty were allowed the same privilege as those which were taken under the Spanish government.

The face of the country had been so much changed by the terrific explosions and commotions of these earthquakes, so many fields, dwellings, and other kinds of property destroyed, that Congress passed the law for their relief before alluded to, but the remembrance of those awful scenes still remains in the memory of the few survivors who witnessed them, and will probably linger around the memory of the past until their eyelids close in "the sleep that knows no waking."

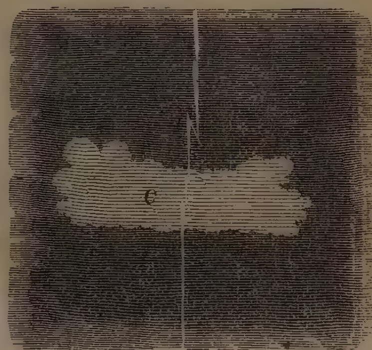
DISPERSION OF A CLOUD BY AN ELECTRICAL DISCHARGE.

FROM D. W. NAILL, OF SAM'S CREEK, MARYLAND.

The accompanying diagram is intended to illustrate an unusual occurrence, so far as I am informed, an account of which is submitted for your consideration.

On the 30th July, 1856, a heavy storm of rain, with some hail and sharp thunder and lightning, occurred at 6 o'clock p. m.

Fig. 1.



A second storm of rain came up at 7 p. m. from the southwest, before which a white cloud of the form represented in fig. 1 was scudding. It was of beautiful whiteness as it appeared between the observer and the dark face of the first cloud. It was a conspicuous object, and I had observed its progress along the face of the Parr Ridge for some two miles, and I should suppose it to have been a mile distant, when a discharge of lightning passed down through it, when it was dispersed or thrown into fragments, as shown in fig. 2.

Fig. 2.

Regarding the occurrence as very unusual, I looked at the slight remains of the cloud from different positions, to satisfy myself that I was not deceived.

Having never observed or heard of such an occurrence before, it has awakened many reflections in my mind in relation to the production of electricity in the clouds, and the offices it performs there, in its amazing power.

CORRESPONDENCE.

COMMUNICATION FROM DR. ROBERT HARE, ON A METHOD OF FORMING SMALL WEIGHTS.*

AUGUST 29, 1856.

I submit, in writing, the proposition respecting the production of small weights which I made to the American Association for the Advancement of Science, at a recent meeting.

In chemical analysis, and in the assay of the precious metals, the accuracy of the extremely minute weights employed is of the utmost importance.

As the government has undertaken to furnish standard weights and measures for the larger operations or transactions of commerce and the arts, without which accuracy and uniformity could not be secured to the country at large, so it would seem consistent that to the minute processes of the arts and sciences a help should be given which otherwise seems not to be attainable.

The usual process of making weights, by reducing them till they exactly counterpoise a standard weight, cannot be pursued advantageously when they are less each than a tenth of a grain. For the making of weights below that size, measurement and division are preferably employed.

An instrument constructed by an ingenious and skilful machinist (Tyler) is capable of dividing an inch into 1,400 parts by the action of a ratchet and wheel, which may be so restricted in its motion as only to move one tooth at a stroke, causing a platform to advance only the fraction of an inch above mentioned.

For producing by means of this instrument tenths and hundredths of a grain, a convenient length of very fine palladium wire may be employed. This being reduced in length very cautiously till it weighs some equimultiple of a grain, a distance commensurate with the length of this wire is marked upon a suitable narrow brass plate by a knife. The number of the ratchet strokes which must be made in order to measure this distance must be ascertained.

Dividing this number by the number of grains will give the number of ratchet movements in a length of the wire equal in weight to a grain; again dividing this by ten will give the number of such movements in a length equal to a tenth of a grain; and, in like manner, if divided by one hundred will give the number of the movements in question requisite to designate the length equal to $\frac{1}{1000}$ of a grain. The length equal to as much of the wire as would weigh a tenth of a grain being thus found, this distance is to be marked on the brass plate with a sharp edge.

A strip of steel is in the next place sharpened at each end to a fine edge, and bent so as to resemble a long narrow staple, is to be furnished midway with a screw, by which the ends can be

* Accidentally omitted in the last report.

made nearer or farther apart, like the points of spring compasses. By these means, with the aid of a lens, the edges of the tool thus constructed are to be made to coincide exactly with the marks designating the length of wire equal to the tenth of a grain.

Having made this adjustment by the action of the tool, ten pieces of the wire being cut and afterwards weighed against a standard grain weight, if found too light or too heavy, the screw regulating the distance must be touched so as to cause the distance to be increased or diminished, rendering the cuts larger or smaller. When they are brought to the weight required, they should, by a delicate assay balance, be tried against each other to ascertain that they are equal in weight to each other.

Having thus obtained tenths of a grain in weight equal to each other, fifths may be made by the same process and tried against the tenths, two to one, and against each other; hundredths may be obtained by a like process; for each a tool being requisite like that used for cutting tenths, excepting that it should be smaller in proportion as the lengths required to be cut are shorter.

The instrument by which these results were obtained has a peculiar capability of reducing the size of the graduations to the limits requisite to include a greater or less number within any necessary length.

Suppose it desirable to have as much of a rod as would be equivalent in bulk to a cubic inch of water divided into such degrees as would increase hundredths of a cubic inch. Let a tube sufficiently large to receive the whole length of the rod be at one end recurved at right angles, and terminated in a point with a capillary orifice. Let the other end be furnished with a stuffing-box to receive the rod, making a water-tight juncture. The tube is to be replete with water, the rod entering so as to reach a little beyond the stuffing-box. A mark is then to be made on the rod as close to the box as possible. A light cup being counterpoised on an accurate balance, and a weight equal to a cubic inch of water being placed in the opposite scale, the apex of the rod is to be introduced into the cup while the rod is shoved in, until as much water has been forced into it from the tube as will balance the weight employed as above mentioned. Another mark is now to be cut into the rod close to the box as before. Thus a length of the rod equivalent to the water excluded, and of course equal to a cubic inch of that fluid, is thus indicated to exist between the knife marks.

The number of ratchet strokes requisite to measure this distance is in the next place to be ascertained and divided by the number of graduations required. The quotient will be the number necessary to make a degree.

Should the number of the ratchet strokes, when decided as above mentioned, leave a fraction, it is to be gotten rid of by means of the contrivance already alluded to for reducing each degree proportionally to any reduction in the whole length necessary to a degree.

I am willing to put the instrument in question into the possession of the government or of the Smithsonian Institution, on condition that it shall be kept in good order for the purpose of furnishing accurate weights, graduations, or measures of liquids or gases, for the purposes of science and the arts.

PLAN OF A BIBLIOGRAPHY.

BY DR. JULIUS FRIEDLANDER.

The daily increase in every department of the sciences by the constant labors of learned men in all parts of the world, resulting in an extensive amount of new researches and speculations has become so large, as to make it impossible for any student of science to keep progress with it. Annual reports on each department have been accordingly felt for many years as an indispensable necessity. The reports on chemistry by Berzelius and Kopp; on botany by Wikström; on zoology by Froschel and others; and those famous ones by the British Association for the Advancement of Science are specimens of such annual reviews. Still these reports but incompletely satisfy the want that is felt. If a philosopher who is about to undertake a new investigation, to study new phenomena, to establish a new hypothesis, or to contrive a new apparatus, wishes to know what has been previously done in the same direction, he has a very laborious undertaking before him, and is obliged to rely upon manuals and encyclopedias merely, unless he has a very extensive library. If he has the latter, he is still in want of a general index. Every man engaged in learned pursuits is constantly appealed to for information as to where this discovery may be found or that experiment detailed.

Many researches are commenced in different parts of the world, and experiments instituted, which have been already pursued and tried many years before, and consequently much valuable time is lost from ignorance of the sources of information whence a knowledge of what has been previously done might have been acquired. The want of a general encyclopedic account of all that has been published on the natural sciences has been long felt, and attempts would have been made to supply this want, could the heavy expense of such a work been covered by private individuals. The literature of natural science is so extensive and diffused through so many periodicals, transactions of academies and learned societies, encyclopedias, and other publications, that when we desire to have access to it we cannot find it in one place, but must visit Berlin, Vienna, London, and Paris, besides various private libraries, and moreover be a bibliographer as well as versed in the sciences.

It certainly seems in character with the objects of the Smithsonian Institution to promote the publication of such a work as is required, and nowhere is its necessity so much felt as in America, and in this Institution, to which such frequent reference is made for the information such a publication would furnish.

In accordance with the expressed desire of Professor Henry, the Secretary of the Smithsonian Institution, I will now proceed to trace out the plan of such a work:

In the first place, I should prepare a general complete bibliographical index of all the memoirs, periodicals, society transactions, encyclopedias, and other collected publications which treat of physics, chemistry, mathematics, and astronomy, as far as I should be enabled

to do so from the bibliographical researches afforded by the public and private libraries of Berlin. Having first published such an index, I would send it to all the large libraries and the eminent scientific men of the world, asking for additional information, while I myself would subsequently compare it with the contents of the different foreign libraries I should visit. By these means, I should be enabled to find out what may remain to be done and to complete the work. A scientific account would then be given of the contents of every publication, and recorded together with its perfect title. The place of publication of each would be given in addition to the title and contents. I should trace out the sources of all extracts and translations together with the original publications, but distinguish them carefully, mark especially where the full description and illustration of apparatus and machines may be found, &c. In this way the titles and contents of about forty or fifty thousand publications would probably have to be recorded and arranged in a systematic order to be afterwards explained. Memoirs which have been translated or republished in different periodicals should be brought under one title, and every source where they can be found noticed, and information given as to where the original was published, and whether the translation or republication be complete or not.

It will be necessary to devote the greatest care and attention to the systematic arrangement of the work. I would certainly not pursue the method of arranging according to authors' names. My classification would be according to the scientific systems, with their various and most extensive subdivisions. This would evidently be by no means the least laborious part of the task.

After the systematic arrangement of the whole, the printing of the work can be commenced in several departments at once. Every title of a publication should have a particular number, and an index of authors' names be added at the end. I may here remark, that it is not intended to embrace the departments of mere technical inventions and machinery, but of all scientific, theoretical and analytical memoirs.

Having thus given a general outline of the proposed work, I will now state to the Smithsonian Institution the conditions under which I offer to undertake it. The sum which I ask from the Smithsonian Institution for the execution of the whole work is $5,000. $2,500 to be paid in eight instalments during the progress of the undertaking, and $2,500 on its completion, *i. e.*, after the printing. 400 well printed copies of the work are to be delivered gratis to the Smithsonian Institution. I will commence with the publication of the preparatory index, the expense of which I shall defray myself. This volume will be the guide to the whole work, and I shall proceed to make all the necessary abstracts from the works mentioned in this first publication and those met with subsequently. By means of the preliminary volume, I shall be enabled to state when the one-eighth of the whole publication will be completed. Baron Alexander de Humboldt, Professor Dove, Professor Magnus, and Professor Poggendorf, with whom I have the honor to be acquainted, are all anxious for the publication of such a work and will undoubtedly be willing to assist its execution. I

would propose also, that it should be submitted to the American ambassador resident in Berlin. To provide for the event of death, I shall assign the work to the latter. When one-eighth of the work shall be completed, I propose that the Smithsonian Institution pay over to me, through the American ambassador, one-eighth of $2,500. I will submit the manuscript to the American ambassador, who will return it to me for the systematic classification.

The manuscript will be completed after a thorough investigation of the libraries of Berlin, Munich, Vienna, London, Paris, Stockholm, the Hague, Brussels, Geneva, Milan and the United States. I shall be allowed the privilege, if desirable, to employ a competent person for the purpose of consulting and making abstracts from the various American publications. The work will be printed on good paper in one of the first German establishments, and be inscribed as a publication of the Smithsonian Institution. Every two months a report of the progress of the work will be made to the Institution, by means of which a proper judgment may be formed of its proceeding. The sale of copies in Europe will cover the expense of printing.

It is only by means of such a work that a scientific person would be able to execute a complete encyclopedia, such as Leibnitz proposed to the academies. Access to such a publication can alone enable a man to discover whether he has all the material of his particular department.

[The Royal Society of London has undertaken to make a general index of all the transactions of learned societies, which will consist of about 250,000 separate titles. It will afford one of the most important means of facilitating the advance of science which has been produced during the present century, and it is to be hoped that provision will be made for a distribution of copies of this work at a small cost to every part of the civilized world. J. H.]

ACCOUNT OF ANTIQUITIES FROM KENTUCKY.

BY S. S. LYON.

I have in my collection a few articles of antiquity, which may be of general interest; should they be deemed of sufficient importance by you, and should you signify your desire, I will pack them up, and send them to the Smithsonian Institution as a donation.* That you may be able to understand what I propose to contribute, I shall give you such an account of them, and a few of the facts in relation thereto, as will fall into the compass of a page or two.

Three miles south of Raleigh, Union county, Kentucky, is the place

* These articles are now in the Smithsonian museum.

from which these objects were procured; from this point to the line of high water of the Ohio there are a great number of mounds and burial places of the original inhabitants of the country, as well as other mounds erected by these people, in which no bodies are found.

The mound from which the remains in my possession were taken is about two or three feet high above the surrounding earth, eighteen feet in its shorter and twenty-one feet in its longer diameter. It is situated at the north end of a flat point or ridge of land. The material taken to cover the bodies which it contains is a fine silicious earth of a recent deposit of this country. (For geological position see map of Union county, Sec. 31, T. 1 S., R. 2 W., near the location of Mr. Leonard Robinson.)

The bodies were laid upon the left side, the heads toward the centre of a circle, and the feet outward. At the head of each was placed one of the earthen vessels, of which there are a great variety of forms and sizes; the largest vessels always being placed at the heads of the adults, smaller ones at those of the younger persons, and the smallest at the heads of the children. Judging from the size of the bodies and condition of the teeth, this burial place contained infants of a very tender age, from six to ten months, and persons of various ages, from childrens to adults of fifty or sixty years of age.

In all cases, without exception, the bodies were laid on the left side, the heads toward the centre of the circle. In some of the vases was found a blackened carbonaceous (?) matter, probably the remains of food, or an offering to the gods of the dead. In addition to the vase, many of the bodies had one valve of one of the unios of the Ohio river placed upon the forehead, the internal side of the shell turned toward the head. In a few cases the larger vases contained a valve of an unio, and all the small vases had a shell within or upon them. Many of the shells accompanying the small vases and those found on the foreheads of the children were carved and ornamented.

The bodies appear to have been laid upon the original surface and covered to the depth of two feet or more; at the heads of some of them the earth is now from twenty-eight to thirty-four inches deep. In all cases where there are bodies in these mounds the surface of the earth has been discolored by fire. The heads of many of the adults appear to have been compressed artificially.

The following is a list of the articles.

1st. Two specimens of extreme cases of compression of the skull.

2d. One round pot with four arms, $4\frac{1}{4}$ inches across the mouth, $4\frac{3}{4}$ inches deep.

3d. One round pot, $3\frac{1}{2}$ inches across the mouth and $3\frac{1}{2}$ inches deep. This is rudely ornamented around the top of the swelled part below the rim.

4th. One bowl, 5 inches wide, $2\frac{1}{2}$ deep, with four prominent points at right angles around the rim.

5th. One bowl, quite well formed, rudely notched around the rim, $6\frac{1}{4}$ inches across the top, $3\frac{1}{2}$ inches deep.

6th. One small deep cup with a handle resembling a bird's head, $3\frac{1}{4}$ inches across the top, $3\frac{1}{4}$ inches deep, $4\frac{1}{2}$ inches to top of handle.

7th. One small cup, found at the head of a child, $2\frac{1}{4}$ inches wide, $1\frac{3}{4}$ inches deep.

8th. Five shells from the foreheads of the skulls; three species of unio.

All the articles being quite fragile they were cleaned when first procured and received a light coat of copal varnish, except the shells. The ornamented shells before mentioned fell to pieces.

In the neighborhood of the locality where these mounds were found are graves differing from those from which these objects were taken. These graves are 29 by 34 inches square, from 7 to 9 inches deep; the bottom and sides lined with black bituminous shale, and contain bones broken into short pieces, as if the bodies had been forcibly thrust in doubled up.

Many additional facts tending to illustrate some of the habits of the aboriginal inhabitants could be procured if desirable.

NOTES ON BAROMETER, RAIN AND SNOW GAGES, &c.

BY R. H. GARDINER.

My experience does not confirm the observation in the 33d page of the pamphlet Directions for Meteorological Observations upon the *fall* of the barometer preceding a storm, and its *rise* during the storm. On the contrary, when the barometer rises considerably above the mean I consider it as an indication that a storm will occur within 31 hours; and when it has not, and I have had an opportunity to learn the state of the ocean on our coast, I have generally learned that it was throwing a heavy sea upon the shore, showing that the storm was not very distant. As soon as the storm commences with us I expect to see the barometer begin to fall and continue to fall till the time when it is about to cease. Professer Cleaveland remarked to me, many years since, that during a storm, as soon as he saw the mercury in the barometer become convex he knew that the storm was about over, and that fair weather might be expected immediately. My experience fully confirms this observation. I consider it a general rule, though I have known exceptions when, in a violent NE. storm, the barometer has risen during the whole continuance.

There are two kinds of clouds proverbially with sailors precursors of stormy weather, *mackerel clouds* and *mare's tails*, which are scarcely sufficiently designated by cirro cumulus and cirro stratus, under which I suppose that they must be classed.

In our cold climate, where we have frequently in the winter rain with the thermometer below 32°, I consider that the rain gage I use is superior to any I have ever seen. It consists of a funnel with an upright copper edge, the superficies of which are exactly a foot

square. The funnel rests in a pail. I have a weight which exactly balances the gage, and every ounce of the water is equal to 0.012 of an inch.

The advantages of this gage are that in the winter season, when we have frozen rain or snow, the amount of rain is ascertained at once, without the labor of melting and without the loss sustained thereby. After it is weighed, a little hot water poured into the gage at once melts the ice or snow. The size of the gage also makes it less liable to error. I do not know how the depth of snow can be measured in a violent storm by any gage. I have a wood of deciduous trees near my house, and after every snow storm I have the snow carefully measured in several places. It rarely varies more than one-half an inch. I take the mean of the different measurements. I consider a foot of dry snow equal to an inch of rain. If the snow is moist I make an allowance.

The aurora is of much more frequent occurrence here than in lower latitudes.

SNOW GAGE.

BY W. E. GUEST, OF OGDENSBURG, NEW YORK.

I beg leave to remark that, during an experience of six years, no better way has occurred to me to get at the true amount of precipitation in the winter season, in this latitude, than the one pursued by myself. As a proof of this, let me give you a description of the weather yesterday: 7 a. m., wind NE.; 2 snow; mild. 11 a. m., wind SE.; 3 hail and rain. Noon, heavy rain. 5 p. m., wind S.; 4 squally, with rain. 6 p. m., wind W., a gale; cold, freezing. This a. m., all froze up.

Had I followed the instructions, viz: to insert the zinc vessel in the snow, sliding under it a tin plate, and then reversing it, very little, if any, could have been obtained. The rain fallen was all ice; the snow was scattered in various piles. But with my tin tube, just the diameter of the rain gage, and two feet in depth, so that what snow gets in is not blown out, and, when the storm is over, bring the vessel into the house, melting gradually and measuring. The tin vessel obtained by myself has a two-inch flange on the bottom to keep it from blowing over, and sometimes it requires props to protect it. Our snow storms are more or less accompanied by wind; and, from the middle of November to the first of April, our rains, which are infrequent, invariably freeze in the falling. The tube you speak of is too small to receive the snow; it would get clogged; and I cannot see the object of placing it below frost; it would be arrested *by* frost in its passage; and the only way to obviate the difficulty known to me is the one above proposed.

OBSERVATIONS ON THE OPENING AND CLOSING OF KENNEBEC RIVER, MAINE.

BY R. H. GARDINER.

My rule for noting the river as closed is when the ice has remained stationary for one ebb tide; as, in that case, I have never known it to move again till there has been rain to raise the river. I have noted the river as open when the ice has come down from above and gone out of sight several miles below. Previous to the erection of the dam at Augusta the river closed from one to two days later at this place and below than above it, and opened proportionably earlier in the spring. Now there is much less difference; the dam, by converting a succession of rapids into a large pond, causes the ice to become much thicker than formerly and the water beneath to be nearer the temperature of the earth. It has also prevented, to a great degree, the breaking up of the ice in the winter. The subjoined account from 1785 to 1803 was taken from minutes made by General Dearborn and continued by Major William Swan.

Opening.	Closing.
1785 April 24.	
1786 March 21	Nov. 18
1787 April 7	
1789 " 4	Jan. 5, 1790
1791 " 3	Dec. 10
1792 " 3	Nov. 23, Dec. 10, [opened after first closing.]
1793 " 1	
1794 " 6	Jan. 4, 1795, [river opened to within two miles of Nehumgeag.]
1796 — —	Nov. 28
1797 April 4	" 22
1798 " 12	" 23
1799 " 13	" 24
1800 " 10	" 28, and Jan. 2, 1801, [opened Dec. 13; ploughing at Christmas.]
1801 March 28	Dec. 10
1802 April 9	" 16
1803 March 22	Nov. 16 and Dec. 22, [vessels come up to Gardiner Dec. 2; whole river opened Dec. 13; closed Dec. 22.]
1804 April 12	Nov. 19
1805 " 2	Jan. —, 1806.
1806 March 15	
1807 April 7	Dec. 18
1808 March 29	" 6, [vessels come up to Gardiner March 27.]

Opening.		Closing.
1809	April 17	Nov. 23
1810	" 9	Dec. 9
1811	March 24	" 14
1812	April 18	" 10
1813	" 11	" 13 and 21, [vessels come up to Gardiner Dec. 15.]
1814	April 6	Dec. 4
1815	" 18	" 2
1816	" 20	Nov. 29, [vessels come to Gardiner April 17.]
1817	April 17	Nov. 25 and Dec. 7, [river broke up from Gardiner Nov. 30; vessels come up to Gardiner Dec. 3; whole river broke up Dec. 7, and closed same day.]
1818	April 12.,	Dec. 4 and 10, [river broke up Dec. 6 and closed Dec. 10.]
1819	April 14	Dec. 5
1820	" 15	Nov. 16 and 29, [river opened Nov. 17 from Gardiner; Nov. 20 whole river opened.]
1821	April 11	Dec. 1
1822	March 29	" 6
1823	April 11	Nov. 16
1824	March 28	Dec. 1 and 9, [opened Dec. 3.]
1825	April 5	Nov. 23 and Dec. 12, [opened Nov. 28.]
1826	April 5	Dec. 4 and 20, [opened Dec. 10.]
1827	March 29	Nov. 24 and Dec. 6, [opened Nov. 30.]
1828	March 25	Dec. 3, [vessels come to Gardiner March 23.]
1829	April 12	Dec. 3
1830	" 1	Dec. 13 and 19, Jan. 11, 1831, [opened Dec. 25 and 27; two vessels arrived from Boston Jan. 1.]
1831	March 30	Dec. 2
1832	April 14	" 2
1833	" 5	" 14
1834	" 3	" 8
1835	— —	Nov. 23
1836	April 9	" 27
1837	" 14	" 27
1838	" 3	" 24, [very great winter freshet Jan. 28, 1839.]
1839	April 6	Dec. 18
1840	March 31	Nov. 28
1841	April 5	Dec 1, 7, and 17, [opened 4 and 11.]
1842	March 20	Nov. 28, [vessels come up to Gardiner March 18.]

Opening.			Closing.
1843	April	19	Nov. 30
1844	"	9	" 27
1845	March	31	Dec. 7
1846	"	28	" 2
1847	April	20	" 21
1848	"	1	" 22
1849	March	30	" 8
1850	April	3	" 8
1851	"	6	" 1
1852	"	12	" 16
1853	March	29	Nov. 27 and Dec. 4, [river opened Nov. 30.]
1854	April	21	Dec. 3
1855	"	9	Nov. 23 and Dec. 11, [opened Dec. 10, and vessels come up.]
1856	April	9	Dec. 1
1857	"	5	" 5

March 26, 1826, the river broke up from a rain that occurred two days previously; the ice struck the roof of a store on the long wharf, which was $21\frac{1}{2}$ feet above high water mark, in some places it piled up much higher; a fishing schooner was crushed to pieces, and the damage done here was estimated at $3,000, and at Hallowell $10,000. The whole river did not break up.

January 28, 1839, river broke up as far as the point below the sands. Cooper's ship-house and ship that was building within it were carried away, as was also the frame of another vessel. A store on long wharf was carried down and lodged on the flats three miles below. Tea and other goods in the store chamber were taken out uninjured, but much damage was done here and in the towns above.

The above record shows that the river opened 17 years in March and 51 years in April; and that the first closing was 26 years in November and 36 years in December.

The mean opening is April 6, and the mean first closing December 2.

The earliest closing is November 16, and the earliest opening is March 15. The latest opening was April 24, 1785, and the next latest April 21, 1854.

Record of earthquakes felt at the Collegiate Seminary of Guatemala in 1857 *and* 1858.

BY A. CANUDAS.

Days.	Hours.	Duration.	Noise.	Intensity.	Motion of a pendulum of 3.5245 metres.	Pendulum with a spiral wire.	Direction.	Aspect of sky.	Wind.
1857.	*h. m.*	*s.*			*Circle described.*				
June 3	2 15 morning.	5	Rumbling	Not strong	4 millimetres		N.NE., S.SW.	Overcast	Calm.
July 15	7 0 "	2		Scarcely sensible	0	Agitated		Overcast	Calm.
Sept. 16	5 31 "	4		Slight	2 millimetres.		N.NE, S.SW.	High fog	E. gentle.
Oct. 14	6 0 "	1	Shock	Slight	0	Agitated		Low fog	N.NW.
Nov. 5	7 30 "	2	Shock and rumbling	Rather strong	0	Agitated	E., W	High fog	N.
6	11 past "		Others felt it		6 millimetres	Agitated	E., W	Cirro-cumulus	E.NE.
7	10 46 "	1	Shock	Scarcely sensible	0	0		Cirro stratus	S.SW.
7	11 0 "		Shock	Very slight	0	0		Cirro-stratus	S.SW.
1858.									
Jan. 3	10 15 "			Very slight	0	0		Cumulus	N.NE.
14	6 7 "	5	Rumbling	Slight	0	0		Overcast	N.
14	11 5 "		Many felt it		0	0		Cumulus	N.NE.
16	3 44 "	2	Rumbling	Rather strong	Very slight oscillation.	0		Heavy rain	
16	5 13 "	2	Rumbling	Rather strong	0	0		Stratus	Calm.

METHOD OF OBTAINING THE AMOUNT OF WATER IN RIVERS.

Information in regard to the amount of water which passes through rivers at different times is an important element in the improvement of internal navigation in the application of hydraulic power, and in the solution of various questions relative to meteorology. The following letter from Captain A. A. Humphreys, of the Topographical Engineers, who has had much experience in gaging rivers, will be of interest to all who are disposed to co-operate in investigations of this character:

Dear Sir: In reply to your request to give suggestions as to the best method of ascertaining the velocity and depth of rivers adapted to amateur observers, I must first observe that any such plan must be rough, as accurate measurements are very expensive.

The most feasible plan for ascertaining the cross section of the river will be to employ a civil engineer to fix the position of a boat by triangulation, while soundings are made from it directly across the river from bank to bank, with a common chain and lead. A time of low water and gentle current should be selected in order to insure accuracy. The contour of the bed between the water surface and high water level must be ascertained by a spirit level. The area of cross section on any day corresponding to any stage can then be readily computed from the reading of a gage-rod when reference to high water is known.

Accurate velocity observations are too delicate and expensive for amateur observers, but fair results may be obtained by the following plan: A base line, say 200 feet in length, is measured parallel to the current. Two range posts are placed at each end. Their lines of direction being perpendicular to the base, and of course parallel to each other, and perpendicular to the current, an observer is placed at each range and a man with a skiff directed to throw over a block of wood in the swiftest part of the current, entirely above the upper range. As this floats past the upper range, the observer shouts to his assistant at the lower, who notes the exact time of its passing the lower range, which he can see for himself. The difference of these times gives the means of computing the velocity, which is equal to 200 divided by it. This velocity is the maximum velocity of the river. The mean velocity is about 0.8 of it. The discharge is, therefore, equal to the area of cross section corresponding to the reading of the gage-rod, multiplied by the observed velocity, multiplied by 0.8.

This method, although rough, will give fair results, if properly carried out. *No instruments are required*, except a *watch* and the *transit* and *level* used by the civil engineers to assist at the soundings.

Your obedient servant,

A. A. HUMPHREYS,
Captain Topographical Engineers.

Prof. Jos. Henry,
Smithsonian Institution, Washington, D. C.

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